Role of "Banker Plants" as a Green Innovation Technology in Integrated Management for *Pectinophora gossypiella* and *Earias insulana* in Egypt Cotton Fields

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Abstract

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This study tested the effectiveness of okra and corn as banker plants with *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatid) release as a green innovation technology for the sustainable management of cotton bollworms *Pectinophora gossypiella* Saunders (Lepidoptera: Gelechiidae) and *Earias insulana* Boisduval (Lepidoptera: Nolidae) in comparison to conventional chemical pesticides and the release of *T. evanescens* alone (control). Results showed that the use of okra and corn and the release of *T. evanescens* were more effective in decreasing the incidence of cotton bollworms in cotton fields than the conventional chemical pesticides or *T. evanescens* alone. The use of okra and corn encouraged the spread of bollworm natural enemies in the treated cotton fields, which had a large impact on the number of cotton bollworm larvae, thus reducing the need for conventional pesticides. Thus, banker plants combined with *T. evanescens* release can support agrobiodiversity and help realize the integrated management of the cotton bollworm and reduce the use of conventional chemical pesticides.

Keywords: Banker plants; *Trichogramma evanescens*, natural enemies, bollworms; agrobiodiversity

Introduction

Cotton is the most abundantly produced natural fiber in the world. More than 103 million tons of textile fibers were consumed in 2019, of which cotton accounted for 24%, chemical fibers 75% and all other natural fibers about 1% (UNCTAD, 2019). In Egypt, the major problem in cotton crop production is the attack by various pests during the different stages of its development, the most important are cotton bollworms, pink bollworm (PBW), *Pectinophora gossypiella* Saunders (Lepidoptera: Gelechiidae) and spiny bollworm (SBW), *Earias insulana* Boisduval (Lepidoptera: Nolidae) (El-Bassouiny *et al.*, 2021; Salama, 1983).

The irrational use of pesticides in cotton fields has sorely affected the population densities of natural enemies. In addition, application of pesticides might bring accelerated appearance of some cotton pests, mostly insects and mites which develop resistance to certain pesticides (El-Bassouiny, 2021). Moreover, pesticides contribute to increasing global warming and climate change (IAASTD, 2009; IPCC, 2021).

Plants release volatile compounds as a response to pests feeding on them. These chemical signals attract the natural enemies (parasites or predators) of these pests and operate in several agricultural species, including cotton, *Gossypium hirsufum* L. (Loughrin *et al.*, 1995; McCall *et al.*, 1993; 1994), corn, *Zea mays* L. (Turlings *et al.*, 2000) and okra, *Abelmoschus esculentus*. The moment that a parasitoid has located a host larva, it injects its eggs into the host, which shortens the feeding life of the host and terminates its reproductive cycle so that the parasitoid (or predator) can propagate (Tumlinson *et al.*, 1993; Turlings *et al.*, 1993).

Although the connection between damage-released plant volatiles and the attraction of the parasites or predators of herbivorous insects has been demonstrated in diverse conditions, the sequence of plant biochemical reactions that trigger volatile release as a response to pest feeding is not yet well understood (Paré & Tumlinson, 1996).

Banker plants are a biological control method that can sustain the management of common pests used in crop production (Jacobson & Croft 1998; Kuo-Sell, 1987; Schoen, 2000). These systems consist of arthropod natural enemies (i.e., predators and/or parasitoids), alternative prey or hosts for the natural enemies, and plants (banker plants) that support the alternative prey or host (Huang *et al.*, 2011). Banker plants increase the effect of biological control conservation strategies (Frank, 2010; Huang *et al.*, 2011; Parrella & Lewis, 2017) by providing an optimal habitat for the natural enemies of pests (Arnó *et al.*, 2000; Gurr *et al.*, 2000; Huang *et al.*, 2011). Banker plants do not require a large production area and easily conform to good agricultural practices. Also, it can help avoid the need for pesticide sprays (Frank, 2010). Increased awareness of the importance of biological control as an alternative to chemical control in crop production is needed (Bompard *et al.*, 2013; Kleespies *et al.*, 2013; Ragsdale *et al.*, 2011; Zappala *et al.*, 2012). Alternative methods safer for the environment than traditional pest control methods are required, since traditional methods further exacerbate climate change. Thus, this study effectively contributes to reducing environmental pollution from the harmful emissions caused by pesticides; thereby, indirectly reducing global warming and climate change.

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Materials and Methods

Experiment design

The experiments were conducted in the 2019 and 2020 cotton growing seasons at the experimental farm of the Plant Protection Institute, ARC, Alexandria, Egypt. A total of 4200 m^2 (Feddan) was cultivated with cotton variety "Giza 86" on April 20^{th} in both years. The experimental area was divided into four treatments of 1050 m² each; (i) corn as banker plants with the parasitoid *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae), (ii) okra as banker plants with *T. evanescens*, (iii) use of *T. evanescens* and (iv) insecticides. A randomized complete design was used with four replicates for each treatment in both years.

Insecticides used

Three biorational insecticides (Kapoor & Sharma, 2020) and known to be effective against bollworms were selected (El-Bassouiny *et al.*, 2015). Those were: emamectin benzoate (MK 244 (Hebei Veyong Bio-Chemical, Shijiazhuang, China) at rate of application of 150 ml/100 L, spinosad (XDE-105; DE-105, Dow AgroSciences Egypt) at rate of application of 50 ml/100 L and methoxyfenozide (RH-2485; RH-112,485, Dow AgroSciences Egypt) at rate of application of 37.5 ml/100 L were used.

Banker plants used

The okra and corn were used as banker plants. They are summer crops whose cultivation coincides with the cultivation of cotton, in addition to being hosts of bollworms. Furthermore, they produce herbivore-induced plant volatiles (HIPVs) that act as cues alert to attract natural enemies of herbivores. Okra and corn were planted as two rows in the treatment plots, the first row at 3.5 m from the edge of the plot, and the second at 7 m from the first row. At the first emergence of cotton fruits, cards of the parasitoid *T. evanescens* were manually hung prior to sunset above the banker plants.

Field release of *T. evanescens*

T. evanescens was released as pupae within parasitized *Sitotroga cerealella* eggs at a rate of around 3 parasites/m^2. The releases were made by using a device that protected the parasites from predators and unfavorable weather conditions. To decrease labor costs, the device was made of a thick paper card (8×12 cm) folded to make a closed container (8×6 cm). Three cards of the Angoumois grain moth (*S. cerealella*) eggs (1×1 cm) containing the parasitoid pupae (*T. evanescens*) at three different stages of development (1, 2 and 3 days pre-emergence) were used. The cards were hung manually before sunset 50cm above the plants. Each feddan required about 42 cards (rate of release: 42 paper cards/feddan/release). The distance between the release points was 7 m, starting 3.5 m from the edges of the field. In both seasons, parasitoids release was conducted after the appearance of the first fruiting branch of the cotton plants.

The inspection of natural enemies

The inspection of the main prevailing predators (non-target predacious) in cotton field was carried out weekly from July 21^{st} to September 23^{rd} during growing cotton seasons of 2019 and 2020. Samples of 25 cotton plants were randomly selected for detecting the predators in each treatment. The monitored predators were: *Chrysopa carnea*. (eggs & larvae), *Coccinlla* spp., *Scymnus* spp., *Orius* spp. in addition to the true spiders. Population reduction rate of non-target predation was calculated and corrected using Henderson & Tilton (1955) equation.

Parasitism and emergence rate (%)

Non-parasitized *S. cerealella* egg cards (10×10 cm) released in the plots field were collected 10 days after placing them to determine the parasitism rate (%), by comparing the total number of eggs to the number of eggs already hatched, and the number of eggs turned black. These counts were done in the lab using binoculars. Afterwards, the cards were placed individually in glass jars with moist filter paper (25±1°C; 70±5% RH). The jar was checked daily for wasp emergence, for16 days after field exposure. Parasitism and wasp emergence rates were then calculated.

Statistical analysis

The data was determined by one-way ANOVA, L.S.D and TUKEY HSD in SPSS version 16.0 software. Differences between treatment means were considered statistically significant at P= 0.05.

Results and Discussion

Effect of the tested chemical and banker plants on the bollworm larvae

Results obtained showed that the use of okra as a bank plant + *T. evanescens* release reduced significantly the number of pink *P. gossypiella* and spiny *E. insulana* bollworms larvae/100 bolls (3.85, 3.22) and (4.75, 4.47) in 2019 and 2020 growing seasons, respectively (Table 1). At the same time, corn + *T. evanescens* release also significantly reduced the number of pink and spiny bollworms larvae/100 bolls (4.5, 3.93) and (5.33, 5.37) in 2019 and 2020 growing seasons, respectively. The insecticide treatment had the third highest impact on pink bollworm larvae/100 bolls (5.95, 5.06) in 2019 and 2020 growing seasons, respectively. The treatment with only *T. evanescens* release had the lowest effect on the pink and spiny bollworm larvae/100 bolls (6.75, 5.95) and (8.89, 8.39) in 2019 and 2020, respectively.

Figure 1 shows that the use of banker plant systems together with *T. evanescens* release was active in controlling *P. gossypiella* and *E. insulana* larvae, with an increased effect on *P. gossypiella* compared to the pesticide treatment (27.9, 22.33) and (43.7, 36.6%) in 2019 and 2020 growing seasons, respectively. The effect on *E. insulana* was almost the same in both seasons, but less in pesticide treatment against *P. gossypiella* (3.44, 3.07) and (14.0, 14.44%) in 2019 and 2020 growing seasons, respectively. The use of *T. evanescens* alone decreased the relative number of *P. gossypiella* and *E. insulana* bollworms (-13.75, -17.59 and -61.05, and -51.44%), respectively, compared to the use of insecticide treatment.

Table 1. Effect of different treatments on mean numbers of bollworms larvae/100 cotton bolls during 2019 and 2020 cotton growing seasons.

	Mean numbers of larvae/100 cotton bolls			
	2019		2020	
Treatments	Pink worm	Spiny worm	Pink worm	Spiny worm
Corn + *Trichogramma*	4.5 ab	5.33 a	3.93 ab	5.37 a
Okra + *Trichogramma*.	3.85 a	4.75 a	3.22 a	4.47 a
Trichogramma only	6.75 c	8.89 c	5.95 c	8.39 c
Chemical insecticides	5.95 bc	5.52 a	5.06 bc	5.54 a

Means followed by the same letters in the same column are not significantly different at P=0.05.

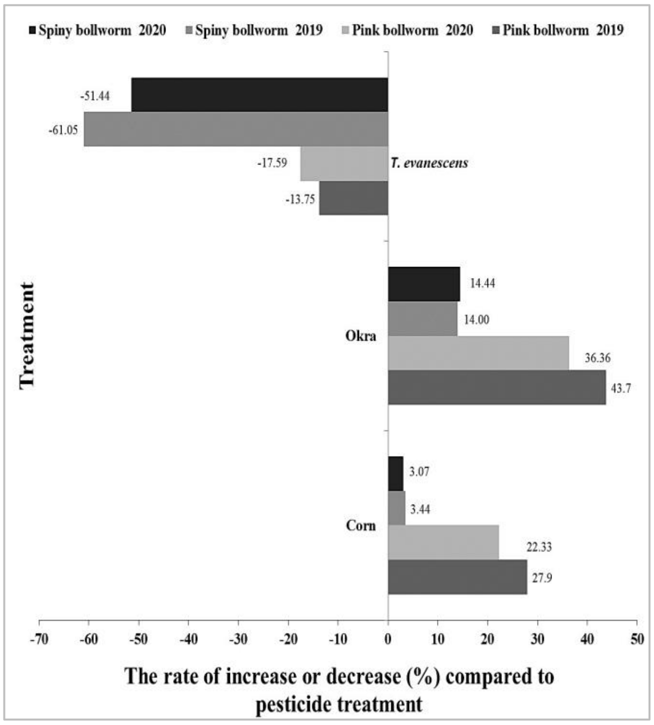

Figure 1. Effect of different treatments on the rate of increase or decrease (%) of bollworms number compared to the pesticide treatment in 2019 and 2020 cotton growing seasons.

The results obtained in this study clearly showed that the use of corn and okra as banker plants paired with *T. evanescens* release were most effective in reducing the number of bollworm larvae. This could have been caused by the different means by which plants can benefit one another (Finch *et al.,* 2003; Ode, 2006; Parolin *et al.,* 2014). Thus, replacing or incorporating the banker plant system with the release of *T. evanescens* in an integrated pest control program is useful in maintaining a high number of biological predators to minimize the effect of harmful insect pests, reduce the use of insecticides, and delay the emergence of insecticide resistance in pest species.

Effect of the tested chemical and banker plants on the biological agents

The results obtained clearly showed that the population of all predator species were much higher when okra was paired with *T. evanescens,* followed by corn paired with *T. evanescens* (Table 2). The conventional insecticides treatments resulted in the lowest predator population in both seasons. The calculated mean number of natural enemies during the two growing seasons showed that the banker plant system increased the predators' chances of survival. *Orius* spp. population density/25 plants is presented in Table 2. The use of okra as a banker plant paired with *T. evanescens* release increased predator population significantly (19.23 and 19.16 individuals/25 plants) in 2019 and 2020, respectively.

Likewise, corn paired with *T. evanescens* release resulted in 18.16 and 18.23 individual predator/25 plants in 2019 and 2020, respectively. The effect of releasing *T. evanescen* alone on *Orius* spp. population ranked third (13.5/25 plants) in both 2019 and 2020 seasons, respectively. The use of insecticides resulted in the lowest number of *Orius* spp. (2.86 and 2.87 individuals/25 plants) in 2019 and 2020, respectively. *Chrysopa carnea* mean number of *larvae* and adults/25 plants were 19.56, 17.5 and 20.36, 18.16 in the okra and corn systems paired with *T. evanescens* release in 2019 and 2020, respectively. The release of *T. evanescens* alone resulted in 12.16 and 14.63 *C. carnea* individuals/25 plants in 2019 and 2020 growing seasons, respectively. The use of insecticides resulted in the lowest number of individuals of this predator in both seasons. During the entire study period (from July 21st to September 23rd in 2019 and 2020), the number of *Coccinella* spp. individuals/25 plants was similar for both the okra and corn systems paired with *T. evanescens* (21.43, 19.23 and 21.36, 21.0 individuals/25 plants) in 2019 and 2020 growing seasons, respectively. The release of *T. evanescens* alone resulted in 11.8 and 12.13 individuals /25 plants in 2019 and 2020, respectively.

The lowest number of predator individuals/25 plants was found in the insecticide treatment (0.4 and 0.5) in 2019 and 2020, respectively. The population density of the true spiders was highest in the okra banker plant system (24.46 and 24.33 individuals /25 plants) in 2019 and 2020, respectively, followed by the corn banker plant system (21 and 19.23 individuals/25 plants). The release of *T. evanescens* alone resulted in 11.63 and 11.6 individuals/25 plants in 2019 and 2020, respectively. The lowest number of true spiders was recorded in the insecticide treatment (0.1 and 0.4 individuals/25 plants) in 2019 and 2020, respectively.

Table 2. The effect of the banker plants together with the release of *Trichogramma evanescens* as compared to insecticides on natural pest predators during the cotton growing seasons 2019 and 2020.

	Mean numbers of natural enemies							
	2019				**2020**			
Treatments	***Orius***	***Chrysopa***	***Coccinella***	**Spiders**	***Orius***	***Chrysopa***	***Coccinella***	**Spiders**
Okra bank plant + *Trichogamma*	19.23 c	19.56 c	21.43 d	24.46 d	19.16 c	20.36 d	21.36 c	24.33 d
Corn bank plant + *Trichgamma*	18.16 c	17.50 c	19.23 c	21.0 c	18.23 c	18.16 c	21.0 c	19.23 c
Trichogamma only	13.5 b	12.16 b	11.8 b	11.63 b	13.5 b	14.63 b	12.13 b	11.6 b
Insecticide	2.86 a	0.23 a	0.4 a	0.1 a	2.87 a	0.26 a	0.50 a	0.40 a

Means followed by the same letters in the same column are not significantly different at P=0.05.

The results obtained in this study are in agreement with many previous studies that have analyzed the use of plants to sustain a reproducing population of natural enemies within a crop system to provide long-term pest suppression (Caballero-López *et al.*, 2012; Lundgren *et al.*, 2009; Huang *et al.*, 2011; Pandey *et al.*, 2020; Sun & Song, 2020). Zhu *et al.* (2020) suggested that sustainable management strategies of rice insect pests reduced the application of chemical insecticides by manipulating biodiversity in non-rice habitats to enhance biological control and to improve ecosystem services.

In addition, Zheng *et al.* (2017) indicated that using a banker plant together with *Trichogramma japonicun* and *Trichogramma chilonis* enhanced natural enemies bank in rice fields to control lepidopteran pests. GholamzadehChitgar (2014) revealed that tested insecticides markedly decreased the mean of bug preys of *Andrallus spinidens*. Mettwally *et al.* (1979) reported that the number of predators was markedly decreased by more than 50% following insecticide application. Zanaty & El-Hawary (1988) reported that pyrethroid insecticides reduced predator populations, with *Chrysopa* spp. less affected than the other predatory insects. Abbas & El-Deeb (1993) examined the population densities of six predators (*Coccinella undecimpunctata*, *C. carnea* [*Chrysoperla carnea*], *Orius albidipennis*, *Paederus alfierii*, *Scymnus* spp. and true spiders) in cotton fields sprayed with several insecticides. The population density of the predators was high in July, and then decreased gradually until the end of the season. They concluded that the insecticide application decreased the number of predators.

Effect of insecticides and the banker plants on *T. evanescens* parasitism and emergence rates (%)

Results obtained indicated that the use of okra and corn as banker plants improved the parasitoid parasitism rate of 80 and 77% in the field, with an emergence rate of 85% and 84% in the lab inspection in 2019 and 2020 growing seasons, respectively, which was superior to the 55% parasitism and 80% emergence rates of *T. evanescens* when used alone (Figure 2). The pesticide treatment had the lowest parasitism and emergence rates of 15 and 10%, respectively.

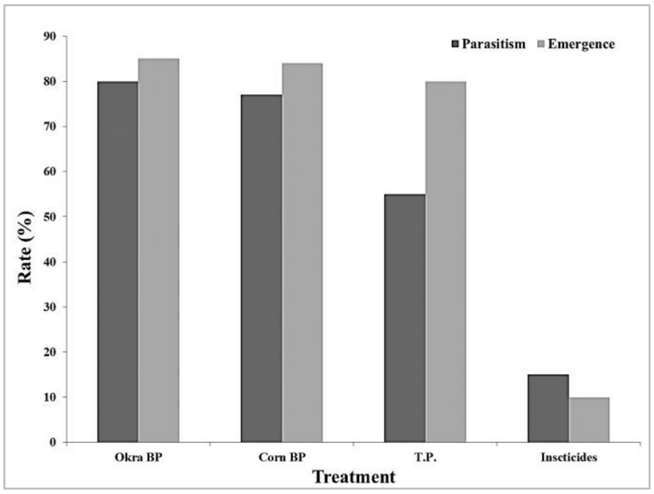

Figure 2. Parasitism and emergence rate (%) following field release tests and lab inspection of *Trichogramma evanescen.* (BP= banker plant, T.P.= *Trichogramma parasitoid*).

The results obtained are in agreement with those of Vianna *et al.* (2009) who reported that the parasitism rates were reduced, also the females emerged from eggs treated with insecticides were not able to lay eggs. Kawamura *et al.* (2001) reported that the insecticides tested showed different degrees of toxicity to the parasitoid *Trichogramma dendrolimi*. Furthermore, Bueno *et al.* (2008) reported that the pesticides esfenvalerate and spinosad were harmful to all immature stages of *Trichogramma pretiosum*. Shoeb (2010) reported that the treatment of parasitoid *Trichogramma evanescens* by lambda-cyhalothrin, spinosad and fenitrothion prevented adults emergency. However, emergence was recorded at a very low rate when the eggs were treated 24 hrs before parasitoid emergence. Female ratio slightly decreased in the adults emerged from parasitized eggs treated with chemicals. Saad *et al.* (2012) showed that *T. evanescens* was significantly affected by the pesticides used to control pink bollworm *(Pectinophora gosspilla*) in cotton. It can be concluded from this study that the green innovation technology banker plants is an additional practice that can reduce or probably eliminate the use of traditional pesticides and their associated negative effects on the environment.

الملخص

مصباح، حسن علي، مجدي عبد الظاهر مسعود، ماجدة بهجت القاضي، زينب محمد هنيدي وهشام محمد البسويني. 2024. دور "نباتات المصدر" كتقنية خضراء رائدة في المكافحة المتكاملة لآفات القطن الحشرية *Pectinophora gossypiella* و *Earias insulana* في حقول القطن في مصر. مجلة وقاية النبات العربية، 42(1): 113–119. https://doi.org/10.22268/AJPP-001213

تمّ تقييم فعالية الباميا والذرة كنباتات مصدر للأعداء الطبيعية مع إطلاق طفيل التريكوجراما كتقنية خضراء مبتكرة للمكافحة المستدامة لديدان لوز القطن القرنفلية والشوكية مقارنةً باستخدام المبيدات الكيماوية التقليدية أو إطلاق التريكوجراما منفردة. أظهرت النتائج أن استخدام الباميا والذرة وإطلاق التريكوجراما كان أكثر فعالية في تقليل الإصابة بديدان لوز القطن في حقول القطن مقارنةً بالمبيدات الكيماوية التقليدية والتريكوجراما منفردة. شجع استخدام الباميا والذرة على انتشار الأعداء الطبيعية لدودة اللوز في حقول القطن المعاملة، وكان لذلك تأثير كبير في عدد يرقات دودة لوز القطن، مما قلّل الحاجة لاستعمال المبيدات التقليدية. وبالتالي، يمكن لنباتات المصدر جنباً إلى جنب مع إطلاق التريكوجراما أن تدعم التنوع الحيوي الزراعي وتساعد على تحقيق الإدارة المتكاملة لديدان لوز القطن وتقليل استخدام مبيدات الآفات الكيميائية التقليدية.

كلمات مفتاحية: نباتات مصدر، ديدان اللوز، الأعداء الحيوية، التنوع الحيوي الزراعي، *Trichogramma evanescens*.

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