Role of “banker plants” in integrated Pectinophora gossypiella (Saunders) and Earias insulana (Boisd.) management

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Research

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Abstract

To reduce global warming caused by the overuse of conventional chemical pesticides used for pest management, this study tested the effectiveness of okra and corn as banker plants with *Trichogramma evanescens* release for the sustainable management of cotton bollworms in comparison to conventional chemical pesticides and the release of *T. evanescens* alone (control). We found that okra and corn with *T. evanescens* release were more effective in decreasing the incidence of cotton bollworms than the conventional chemical pesticides or *T. evanescens* alone. We also found that 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 by reducing the use of conventional chemical pesticides and contributing to global warming reduction.

Introduction

Banker plant systems are a biological control method that pairs secondary plants to main crops. The secondary plants support parasite (or predator) colonies that have either been reared or brought in on the secondary plants. Thus, banker plant systems play an active and dynamic role in mediating the interaction between herbivorous insects and their natural enemies (Paré and Tumlinson, 1997). In fact, the addition of secondary plants to crops is a promising method for pest management (Parolin et al., 2012), as the dissimilarity of the banker plants in comparison to the main crops ensures that the parasites have more pests to feed on, which results in them remaining in the field longer.

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.; McCall et al., 1993, 1994; Loughrin et al., 1995), 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 and Tumlinson, 1996).

Banker plants are a biological control method that can sustain the management of common pests used in crop production (Kuo-Sell, 1987; Jacobson and Croft, 1998; Schoen et al., 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 (Parella and Lewis, 2017; Frank, 2010; Huang et al., 2011) by providing an optimal habitat for the natural enemies of pests, thus promoting its survival, longevity, and reproduction by providing food and shelter (Arnó et al., 2000; Gurr et al., 2000; Huang et al., 2011). Banker plants that do not require a large production space and that can easily conform to good agricultural practices are preferred. In addition, banker plants can help avoid the need for pesticide sprays (Frank, 2010).

Recent studies reviewed the use of secondary plants in crops and the area surrounding crops and highlighted their most important functional characteristics to improve pest management (Parolin et al., 2012a, b

Pests can be added to the list of anticipated negative effects of climate change, with increased floods, droughts, and wildfires. Longer growing seasons and a warmer climate allow weeds and insect pests to proliferate, which will most likely lead to increased pesticide use, which further increases the harmful emissions that further exacerbate climate change. This cycle could potentially be broken by embracing regenerative methods (e.g., banker plant system) in agricultural pest control that could reduce pesticide use.

The report from the Intergovernmental Panel on Climate Change found that about 30% of global emissions leading to climate change are attributable to agricultural activities, including pesticide use Californians for Pesticide Reform (CPR). More than 200 million pounds of agricultural pesticide active ingredients are applied to California fields each year, of which more than 40 million pounds are fumigants, which are among the most hazardous and greenhouse gas-producing pesticides (CPR).Fumigant use has been shown to contribute to nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide (IAASTD, 2009). Koleva et al. (2010) found that climate change likely increases the toxicity risk to aquatic species by 47% due to the increased application of agricultural pesticides, with more than 90% of climate change in the aquatic environment induced by impacts of pesticide pollution.

Countries around the world are now recognizing the unique role that agriculture can play in sequestering carbon. Nearly the entire European Union has joined a host of nations in signing the international initiative “4 per 1000” in the Lima-Paris Action Agenda, which is officially recognized by the Paris Climate Accord. The initiative recognizes that a 4% annual growth rate of soil carbon stock would make it possible to stop the present increase in atmospheric CO_2. The participating countries are called on to achieve this goal by scaling up their regenerative farming, grazing, and land-use practices with a focus on soil health.

Increased awareness of the importance of biological control as an alternative to chemical control in crop production is needed (Bompard et al., 2013; Desneux et al., 2010; Kleespies et al., 2013; Ragsdal 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.

Materials And Methods

Experiment design:

The experiments were conducted in the 2019 and 2020 cotton growing seasons at the experimental farms found at the Agricultural Research Center at the Plant Protection Station, Plant Protection Institute of the Alexandria Government in Egypt. One feddan (1050 m^2) was cultivated with cotton variety "Giza 86" on April 20th in both years. The experimental area was divided into four treatments of 0.25 feddan (350 m^2) each (corn as banker plants with *T evanescens,* okra as banker plants with *T. evanescens*, only *T evanescens* and insecticides. A randomized complete block design was used with three replicates for each treatment in both years.

Insecticides used:

Three biorational insecticides were selected, encompassing a wide range of insecticides types with the general traits of being relatively non-toxic with minimal side effects to the ecology. Biorational insecticides are known to be effective against bollworms El-Bassouiny et al., 2015.

The three biorational pesticides were emamectin benzoate, spinosad and methoxyfenozide were used in sequential to control bollworm

Emamectin benzoate:

MK 244 (Hebei Veyong Bio-Chemical, Shijiazhuang , China)

Rate of application: 150 cm^3/100 L

Spinosad

XDE-105; DE-105 (Dow AgroSciences Egypt).

Rate of application: 50 cm^3/100 L

Methoxyfenozide:

RH-2485; RH-112,485(Dow AgroSciences Egypt).

Rate of application: 37.5 cm^3/100 L

Banker plant:

We used okra and corn as banker plants, which were planted in rows in two of the treatment plots at a distance of 7 m from the edge of the plot for the first row, then at a distance of 14 m for the other rows. with the emergence of the first fruitful branch of the cotton plant cards of the parasitoid *T. evanescens* were manually hung prior to sunset above the banker plants.

Field release of *T. evanescens*:

T. evanescens were released as pupae within parasitized *Sitotroga cerealella* eggs at a rate of 6000 parasites/faddan. The releases occurred using a device that protected the parasites from predators and unfavorable weather conditions. To decrease labor costs the device, which consists of a thick paper card (8 x 12 cm.) was folded to make a closed container (8 x 6 cm.). Three cards of the Angoumois grain moth (*S. cerealella*) eggs (1 x 1 cm.) containing the parasitoid pupae (*T. evanescens*) at three different stages of development (1, 2, & 3 days pre-emergence) were hung. The cards were hung manually before sunset 50 cm above the plants. Each feddan required about 22 cards (rate of release: 22 paper cards/feddan/release). The distance between the release points was 14 m, starting 7 m from the edges of the field. In both seasons, parasitoid release was conducted after the appearance of the first fruiting branch of the cotton plants.

Parasitism and emergence rate (%):

Non-parasitized *S. cerealella* egg cards (10 cm X 10 cm) which released in the plots field were collected after 10 days 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 d after field exposure. Parasitism and wasp emergence rates were then calculated.

Results

Effect of the tested chemical & banker plants on the number of bollworm larvae

Table (1) shows the mean number of pink and spiny bollworms after the various treatments. We found that okra paired with *T. evanescens* release (banker plant system) was the most effective at reducing the number of pink and spiny bollworm larvae/100 bolls (3.85, 3.22) and (4.75, 4.47) in 2019 and 2020, respectively. Corn paired with *T. evanescens* release ranked second in terms of impact on the number pink and spiny bollworm larvae/100 bolls (4.29, 3.93) and (5.33, 5.37) in 2019 and 2020, respectively. The insecticide treatment had the third highest impact on pink bollworm larvae/100 bolls (5.95, 5.06) in 2019 and 2020, respectively; however, corn used as a banker plant with *T. evanescens* had a similar effect on spiny bollworm larvae/100 bolls (5.52, 5.54) in 2019 and 2020, 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.

Fig (1) shows that the banker plant systems (okra and corn) paired with *T. evanescens* release was successfully used to control bollworm larvae, with an increased effect rate on pink bollworms compared to the pesticide treatment (27.9%, 22.33% and 43.7%, 36.6%) in 2019 and 2020, respectively. The effect rate on spiny bollworms was almost the same in both years, but showed less of an increase compared to the pesticide treatment than against the pink bollworms (3.44%, 3.07% and 14%, 14.44%) in 2019 and 2020, respectively. The release of *T. evanescens* alone decreased the rate of influence on the pink and spiny bollworms (−13.75%, −17.59% and −61.05%, −51.44%) respectively, compared to the insecticide treatment.

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

Table (2) and Figs. (2 & 3) show the effect of the tested insecticides and banker plants (okra or corn) paired with the release of *T. evanescens* on the inspected predators. The results clearly show that the counted populations of all predator species were much higher when okra was paired with *T. evanescens*, followed by corn paired with *T. evanescens*. The conventional insecticides treatments resulted in the lowest predator populations. The calculated mean number of natural enemies during both growing seasons showed that the banker plant system increased the predators’ chances of survival. Thus, the insecticides had an effect on the number of predators, decreasing their populations to a great extent during both seasons.

Orius spp.

The population density of the *Orius* spp./25 plants is presented in Table (2) and Figs. (2 & 3). The use of okra as a banker plant paired with *T. evanescens* release resulted in 19.23 & 20.6 individuals/25 plants in 2019 and 2020, respectively. Corn paired with *T. evanescens* release resulted in 18.16 & 17.5 individuals/25 plants in 2019 and 2020, respectively. The release of *T. evanescen* alone ranked third in its effect on *Orius* spp. (13.5 and 12.03 individuals/25 plants) in 2019 and 2020, respectively. The use of insecticides resulted in the lowest number of *Orius* spp. (2.86 and 2.9 individuals/25 plants) in 2019 and 2020, respectively.

Chrysopa carnea

The mean number of *C. carnea* 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. The release of *T. evanescens* alone resulted in 12.16 and 14.63 individuals/25 plants in 2019 and 2020, respectively. The use of insecticides resulted in the lowest number of individuals in both seasons.

Coccinella spp.

During the entire study period (from July 21st to September 23rd in 2019 and 2020), the number of individuals/25 plants of *Coccinella* spp. was similar for both the okra and corn systems paired with *T. evanescens* (21.43, 19.23 and 21.36, 21 individuals/25 plants) in 2019 and 2020, 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 individuals/25 plants was found in the insecticide treatment (0.4 and 0.5) in 2019 and 2020, respectively.

True spiders:

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 and11.6 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.

Parasitism and emergence rates (%)

Fig. (4) shows the parasitism and emergence rates (%), which indicate that the use of okra and corn as banker plants was successful, with a parasitism rate of 80% and 77% in the field and an emergence rate of 85% and 84% in the lab inspection in 2019 and 2020, respectively, which was superior to the parasitism (55%) and emergence rates (80%) of *T. evanescens* alone. The pesticide treatment did not succeed at all and had the lowest parasitism and emergence rates of 15% and 10%, respectively.

Discussion

In this study, we recommend the introduction of a new term ("biocontrol plants") to refer to those secondary plants that can be specifically used to enhance biological control in integrated pest management systems (Parolin et al., 2014). We hope that the use of this term will improve the ease of implementation for integrating different types of secondary plants into cropping systems (banker plant). We also hope that it will increase the search ability for biocontrol plant species that are best suited for a given crop or ecosystem, especially those found within the local flora.

Our results showed the action and effect of the tested banker plants and insecticides on cotton bollworms during the 2019 and 2020 cotton-growing seasons. The results clearly show that the use of corn and okra as banker plants paired with *T. evanescens* release were most effective in sharply reducing the amount of bollworm larvae. This could have been caused by the different means by which plants can benefit one another, which directly influences the first trophic level (Kuepper and Dodson, 2001; Finch et al., 2003; Ode, 2006):

1. Flavor enhancer: some plants alter the flavor of other plants;

2. Nitrogen fixing: legumes fix atmospheric nitrogen by utilizing *Rhizobium* bacteria; although this is for their own use, it also benefits neighboring plants;
3. Protection and shelter: tall plants may protect other species by providing shade and/or a windbreak;
4. Biochemical pest suppression: some plants produce chemicals that suppress or repel pests and protect neighboring plants.

Thus, these results indicate that 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. Our results agree those of 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 (e.g.,., Berlinger et al., 1996; Bottrell et al., 1998; Caballero-Lopez et al., 2012; Huang et al., 2011; Lundgren et al., 2009; Wäckers et al., 2005). Metwally et al. (1979) found that the numbers of predators markedly decreased by more than 50% following insecticide application. Zanaty and El-Hawary (1988) reported that pyrethroid insecticides diminished predator populations, with *Chrysopa* spp. less affected than the other predatory insects. Abbas and 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 numbers of predators. Finally, Saad et al. (2012) showed that *T. evanescens* was significantly affected by the pesticides used to control pink bollworm *(Pectinophora gosspilla*) in cotton.

Conclusion

This study shows that banker plants epitomize a positive contribution to the search for new pest management practices by reducing or eliminating the use of traditional pesticides and their associated negative effects on the environment (e.g., pollution, global warming) to achieve integrated pest management. In this study, the selected banker plants outperformed the traditional pesticides in reducing the cotton bollworm population and encouraging the survival of natural enemies. In light of global warming and climate change, our study provides a new alternative pest management strategy that increases and encourages the reproduction of natural enemies to create a fair and balanced ecosystem.

Declarations

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Tables

Table (1): Mean Numbers of bollworms larvae / 100 bolls in both seasons of cotton filed.

Treatments	Mean Numbers of larvae / 100 bolls			
	2019		2020	
	pink	Spiny	pink	Spiny
Corn Banker Plant	4.29^{c}	5.33^{b}	3.93^{c}	5.37^{b}
Okra Banker Plant	3.85^{c}	4.75^{c}	3.22^{d}	4.47^{c}
Trichogramma	6.75^{a}	8.89^{a}	5.95^{a}	8.39^{a}
insecticides	5.95^{b}	5.52^{b}	5.06^{b}	5.54^{b}
$LSD_{.05}$	0.48	0.70	0.53	0.68
Significant	***	***	***	***

Table (2): The side effect of the banker plants system with the release of *Trichogramma evanescens* and insecticides on the biological agents during the cotton growth seasons 2019 and 2020.

Treatments	Mean Numbers of Natural enemies							
	2019				2020			
	Orius	*Chrysopa*	*Coccinella*	spiders	Orius	*Chrysopa*	*Coccinella*	spiders
Okra B.	19.23^{a}	19.56^{a}	21.43^{a}	24.46^{a}	20.6^{a}	20.36^{a}	21.36^{a}	24.33^{a}
Corn B.	18.16^{b}	17.5^{b}	19.23^{b}	21^{b}	17.5^{b}	18.16^{b}	21^{a}	19.23^{b}
Trichochramma	13.5^{c}	12.16^{c}	11.8^{c}	11.63^{c}	12.03^{c}	14.63^{c}	12.13^{b}	11.6^{c}
Insecticide	2.86^{d}	0.23^{d}	0.4^{d}	0.1^{d}	2.9^{d}	0.26^{d}	0.5^{c}	0.4^{d}
$LSD_{.05}$	0.92	1.171	0.99	0.84	0.88	0.99	1.00	0.88
Significant	***	***	***	***	***	***	***	***

Figures

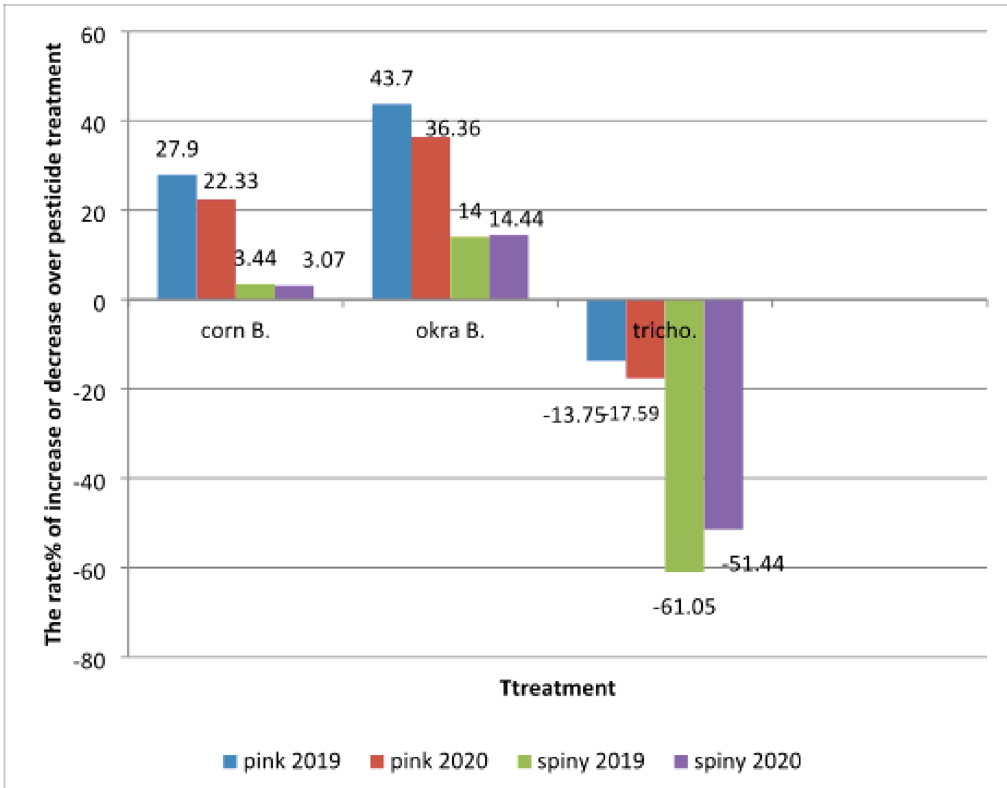

Figure 1

The rate % of increase or decrease on influence bollworms over pesticide treatment in both seasons (2019 and2020) of cotton filed.

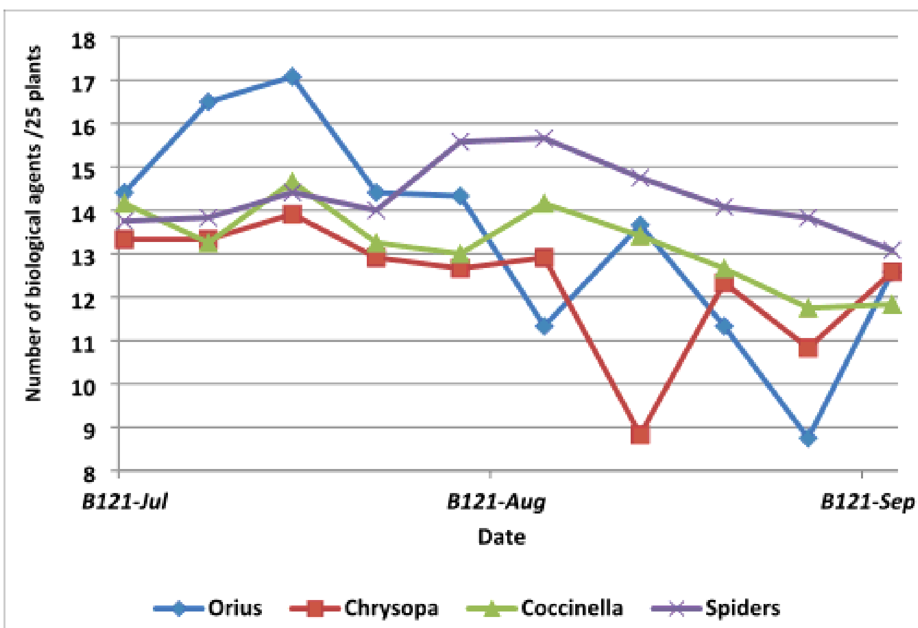

Figure 2

The inspections mean number of biological agents during the whole period of (extending from July the 21st up to September the 23rd in the cotton growth season 2019.

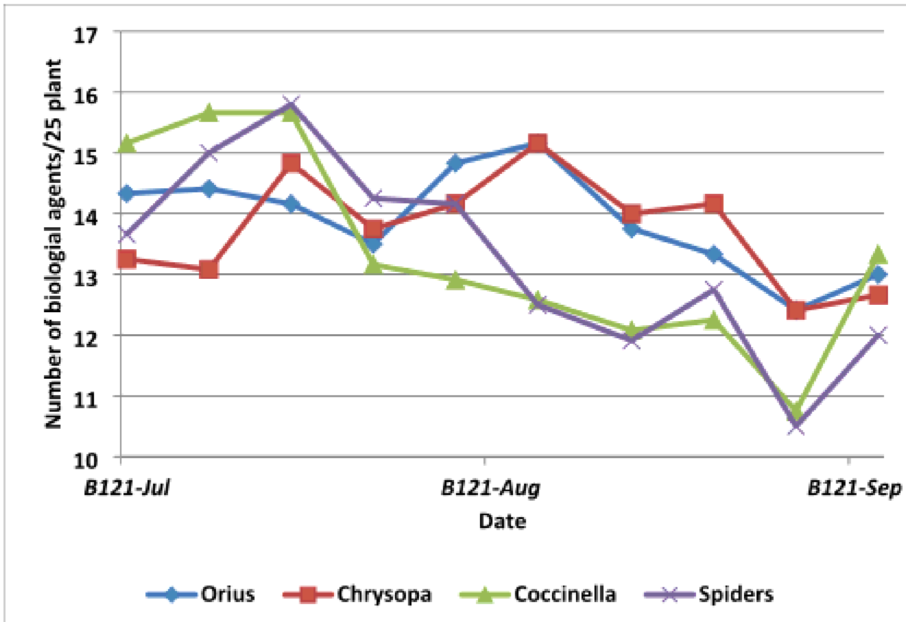

Figure 3

The inspections mean number of biological agents during the whole period of (extending from July the 21st up to September the 23rd in the cotton growth season 2020.

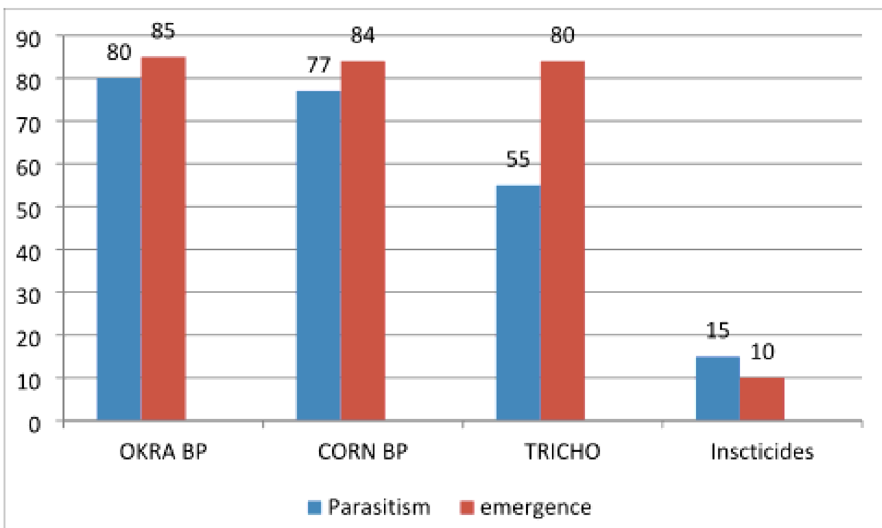

Figure 4

Parasitism and emergence rate (%) in Field release tests and lab inspection of *Trichogramma evanescen*.