ASSESSING THE ECONOMICAL IMPACT OF TRICHOGRAMMA BIO-CONTROL IN THE MANAGEMENT OF PINK BOLLWORM (*PECTIONOPHORA GOSSYPLELLA*) AND SPINY BOLLWORM (*EARIAS BIPLAGA*) INFESTATIONS IN EGYPTIAN COTTON FIELDS.

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ABSTRACT

The present paper attempts to measure the impact of the biological control of Trichogramma, a parasitoid of the pink bollworm (Pectionophora gossyplella) and Spiny Bollworm (Earias biplaga), on cotton production during 2005, and over a large area (1300 feddan). Results attributed the observed improvement of cotton production to the success of biological control. The economic impact of the introduced parasitoid are demonstrated relying on production yielded, costs incurred, infestation ratio, crop loss and B/C ratio. Total revenues for producers who adopted biological control programme, gained 8% higher than those who used the conventional chemical control. Extrapolated to all producers of cotton, a foregone income of LE 282 million in cotton production can be estimated. Trichogramma accrued a crop loss estimated at 3.1% compared to nearly 15% per feddan for chemical control. Moreover, the benefit–cost ratio for bio-control cotton is estimated at 66:1 compared to 29:1 for chemical controlled.

Keywords: Trichogramma, Pink bollworm, Spiny bollworm, Cotton, Egypt

1. INTRODUCTION

Cotton is very prone to insect infestation and large quantities of the most acutely toxic insecticides are used in conventional cotton production. It accounted for about 24 per cent ($1,776 million) of the global insecticides market in 1994, even though the crop occupied only 2.4 %of the world's total arable land. It is clear that the quantity of chemicals used is disproportionate to the size of the area under cotton.

The use of pesticides often leads to serious environmental problems besides affecting the health of users and consumers. They also eliminate the natural enemies, creating the need for more pesticides, increasing production costs, and the development of insecticide resistance. To overcome resistance, farmers in Asia resorted to increasing frequency and doses of pesticide applications and to insecticide cocktails (Talekar and Shelton, 1993). Moreover, figures for poisonings and deaths related to pesticide use reflect these problems. Myers and Stolton (1999) argued that, 'in developing countries up to 14 per cent of all occupational injuries in the agricultural sector and 10 per cent of all fatal injuries could be attributed to pesticides. In addition, these problems are not restricted to developing countries, in California, cotton ranked high for the total number of worker illnesses caused by pesticides. Moreover, methods of applying the pesticides can compound the problem, especially aerial spraying which is common in the US, Australia, Egypt and Uzbekistan'. Therefore, alternative new pest-control methods have begun to become available. One such method is the use of biological control.

Biological control is the use of predators, parasites and disease to control pests. Important natural enemies in cotton include minute pirate bugs, damsel bugs, big-eyed bugs, assassin bugs, lady beetles, lacewing larvae, syrphid fly larvae, spiders, ground beetles and a variety of tiny wasps that parasitize the eggs, larvae and pupae of many cotton pests. Biological control includes the conservation, importation and augmentation of natural enemies. In other words, existing populations of natural enemies are conserved by avoiding the use of insecticides until they are needed to prevent the development of economically damaging pest infestations. Classical biological control is the importation of natural enemies from other countries. Augmentation involves the purchase and release of natural enemies on a periodic basis. Trichogramma is one of the most notable commercially available natural enemies that are environmentally safe (Baugh et al., 2005).

In Africa, impact evaluation of biological control started with the biological control of the cassava mealybug. It was assessed using secondary data and by extrapolation of major assumptions of increased yield that found a benefit cost ratio of 149:1 (Norgaard, 1988). A more recent study by Zeddies et al., (2001) with a detailed modeling for 27 countries and an extrapolation over a 40-year period confirmed its positive results. The impact of biological control of the mango mealybug was first evaluated qualitatively (Vogele et al., 1991), and later quantitatively based on farmer's interviews (Bokonon-Ganta et al., 2002) also resulted in a high benefit cost ratio of 145:1. It is important to note that the results were derived from low area coverage and a limited data set. However, the most recent project on water hyacinth biological control (De Groote et al., 2003) was the first attempt to assess the impact of a biological control project based on data collected from direct beneficiaries. Farmers' participation is highly being sought to improve the evaluation of new technologies, including biological control (Mueller et al., 2002; De Groote et al., 2001;

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Winters and Fano, 1997). However, the most recent study by Macharia, et al., (2005) assessed the potential economic impact of the introduction of Diadegma semiclausum, an exotic parasitoid of the diamondback moth (Plutella xylostella, DBM), on cabbage production in Kenya. Whereas, in Philippines, Rendon, etal., (1998) conducted a study to investigate the impact of Trichogramma on corn production in Bukidnon. The study revealed that comparative cost of control showed Trichograma bio-control is economical to use which is 28.88% to 32.91% cheaper than insecticide control. In addition, an estimated increase of 44 tons of corn has been achieved by the farmers upon adoption of Trichogramma.

Cotton is the most important fiber and commercial crop in the world as well as in Egypt. In 2004, Egypt is ranked the fourth all over the world in exporting cotton lint with a share in the world market estimated at 5% (FAO, 2004). Its cultivated area accounted 714 thousand feddan (one feddan = 0.42 ha) representing 20% of total planted summer season area. Thus, increasing cotton production and quality is an urgent national goal to meet the consistent demand for this crop. However, cotton is highly pest prone; in which important pests affecting cotton are leafhoppers, thrips, cotton aphids, whiteflies, red spider mites, red cotton bug, pink bollworm, spiny bollworm and the American bollworm (Sawan et al., 2000).

This paper is organized as follows; Section 2 and 3 discuss the aim of the paper and data used. Section 4 gives a brief description for Pink and Spiny bollworms and Trichogramma way of action. Section 5 reports the results of analysing the impact of bio and chemical control on cotton in terms of infestation ratio, crop loss, yield, control costs and B/C ratio. Finally, Section 6 is devoted to conclusion.

2. Aim of the Paper

This paper evaluates the potential economic impact of the introduction of Trichogramma, a parasitoid of the pink bollworm (*Pectionophora gossyplella*) and Spiny Bollworm (*Earias biplaga*), on cotton production at field conditions.

3. Data

Data collection was conducted by Pest Control Departments in Tanta, Basyoun, Kafr El-Zyat and Zefta districts (supported by the Ministry of Agriculture and Land Reclamation) during the agricultural season 2005 in Gharbia governorate. In which, an experiment was performed to introduce Trichogramma parasitoid as an alternative to the traditional chemical control for pink and spiny bollworms. In chemical control treatment, the normal pesticides used by most growers were applied (mainly phosphorus compounds) that are on liter of each Atabrunn, Tafaban, and Pestpan, in addition to Tlethion (750 ml) and Snethor (50 ml) per feddan. The experiment included nearly 1300 feddan (among 46 fields) covering four districts, where 47% of the area devoted to bio-control and 53% to chemical control, that were at certain distance from each other. The production, costs and infestation ratio data were obtained through investigations carried by the Ministry of Agriculture team. At least 100 blind boll samples were collected every five days during the period from 06/07/2005 to 15/09/2005 from each field for each treatment. The bolls were split in the laboratory and examined to determine infections with pink and spiny bollworm larvae.

4. Background.

4.1 Pink and Spiny Bollworms

Pink bollworm is mainly a mid and late season pest of cotton. It is observed worldwide and damages more than 70 plant species. Pink bollworms Adults' are small, grayish brown and inconspicuous moths. When their wings are folded, they have an elongated slender appearance. The wing tips are conspicuously fringed. Young larvae are tiny, white caterpillars with dark brown heads. When mature, they are about 0.5 inch (12 mm) long and have wide transverse pink bands on the back. Eggs are very small, slightly elongated, and laid under the calyx of green bolls. Pink bollworms damage squares and bolls, the damage to bolls being the most serious. Larvae burrow into bolls, through the lint, to feed on seeds. As the larva burrows within a boll, lint is cut and stained, resulting in severe quality loss. Under dry conditions, yield and quality losses are directly related to the percentage of bolls infested and the numbers of larvae/boll. With high humidity, it only takes one or two larvae to destroy an entire boll because damaged bolls are vulnerable to infection by boll rot fungi. However, the harm caused by pink bollworm can be found from blooming of cotton to the end of the harvest period.

According to Unlu and Bilgic (2004), the current yield may be affected by two important ways: the effect of the larvae stemming from the earlier period and the effect of the adults of pink bollworm stemming from the neighboring fields. The means for the transition of the pests from one season to the next and the source of infestation are the blind bolls left in the fields after the harvest. In addition, after the harvest of cotton, the mature larvae lasts till the winter period. The effects of the residuals play an important yield loss during the next period.

However, the spiny bollworm is an important cotton pest and found wherever cotton is grown in middle eastern countries such as, Egypt, Syria and Turkey. The caterpillar grows to a length of 15-18 mm long and is greyish with black spots and markings. The adult moth has a wingspan of 20-22 mm. The wings are straw coloured with a few distinct lines across the front wings. In other countries, these species are reported to have green wings or fields of green across the wings. The colour depends on temperature and other environmental factors. The harms caused to the blooms are negligible but are profound in bolls. As the larvae of spiny bollworm penetrated the bolls, it is difficult to control early detection of the pest and thereby its effective management.

4.2 *Trichogramma*

Trichogramma are minute wasps, less than 0.5 mm long. They are egg parasites that parasites on a number of insect eggs (of which, pink and spiny bollworms). The adult female lays her eggs into hosted (bollworm) eggs. When the wasp eggs hatch, the larvae devour the developing worm inside the hosted egg. The Trichogramma larvae pupate and develop into fully formed wasps inside the hosted eggs, which turn black as the wasps develop inside. Wasps emerge by chewing a hole in the host egg and are then ready to parasitize other hosted eggs. This process takes between seven and ten days, depending on the temperature. A female wasp can parasitize over fifty hosted eggs during her 5 – 14 day life. Mated female wasps will produce both male and female offspring. Unmated females can parasitize eggs but will produce only male offspring. Trichogramma should be released when moths are active and laying eggs.

At release, Trichogramma are dispatched in the form of parasitized moth eggs. The eggs are distributed in capsules, each containing 1000-parasitised moth eggs. Each capsule should be stapled through one corner to a leaf or post. In hot weather, a shady spot should be selected. The wasps will gradually move downwind, so placing any extra capsules is desirable. After release, the hatched female wasps will seek out suitable host eggs, preferably freshly laid ones, in which to lay their own eggs. It may take a number of releases and generations before parasitism increases to high levels. Although the level of parasitism is a useful indicator of Trichogramma activity, overall control of pink and spiny bollworms is better determined by the number of developed caterpillars present and actual damage to the crop.

5.Assessment

5.1 Economic Impact

The economic assessment would cover the impact of conventional chemical control and the alternative biological control on infestation ratio, productivity, crop loss, control costs and benefit-cost ratio.

5.1.1 Infestation ratio and Productivity

Figures 1 and 2 present the differences in infestation ratios and yields for Trichogramma bio control and traditional pesticides chemical control. Lab results indicated that pink bollworm infestation constituted the majority in both bio and chemical controlled fields that accounted 98% and 93% respectively. In other words, Trichogramma bio-control showed more effectiveness in reducing spiny bollworm infestations and controlling pink bollworm infestations. Because spiny bollworm infestations constituted small percentage (2% -7%), and to avoid extrapolating into an area without data, pink and spiny infestation ratios were merged.

Infestation ratios for Trichogramma and chemical pesticides control in the four districts seem to deviate substantially from each other (Fig 1). The results depict a significant fall in infestation ratio for bio-controlled compared to chemical controlled fields by 37.5%, in which the infestation ratios is estimated at 10% (on average) for the former and 16% for the latter. Moreover, Infestation ratio was found to be statistically significant at 1% level of significance ($P=0.000$; $N = 46$; $F= 30$) across biological and chemical control.

Economic impact is also reflected in the average yield figures. In general, bio-controlled fields showed higher yields than chemical controlled estimated at 8% (Fig 2). However, bio-controlled yields accounted 8.0, 8.4, 6.1and 8.3 kentar (Egyptian measure of cotton, one kentar = 157kg) /feddan (on average) in Basioun, kafr El-Zayat, Zefta and Tanta respectively compared to 7.3, 8.2, 5.5 and 7.5 kentar /feddan (on average) for chemical controlled fields. Moreover, yield was found to be statistically significant at 1% level of significance ($P=0.000$; $N = 46$; $F= 41$) across biological and chemical control.

FIGURE (1): TRICHOGRAMMA VS CHEMICAL CONTROL INFESTATION RATE.

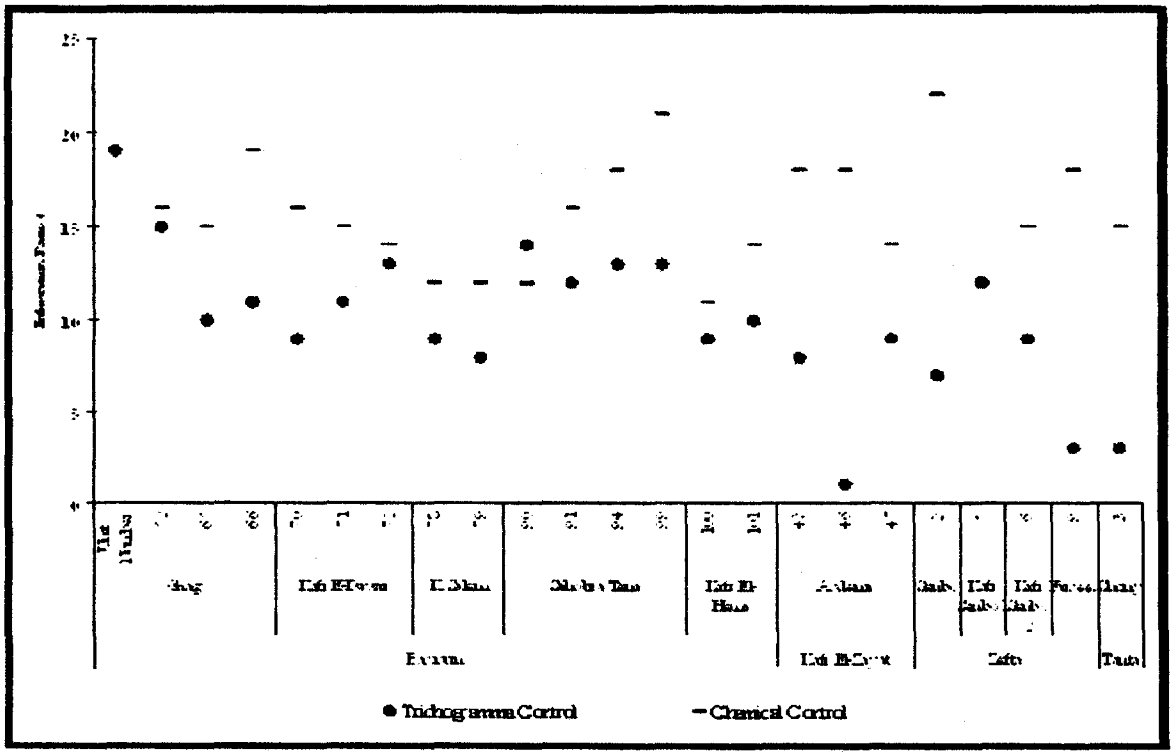
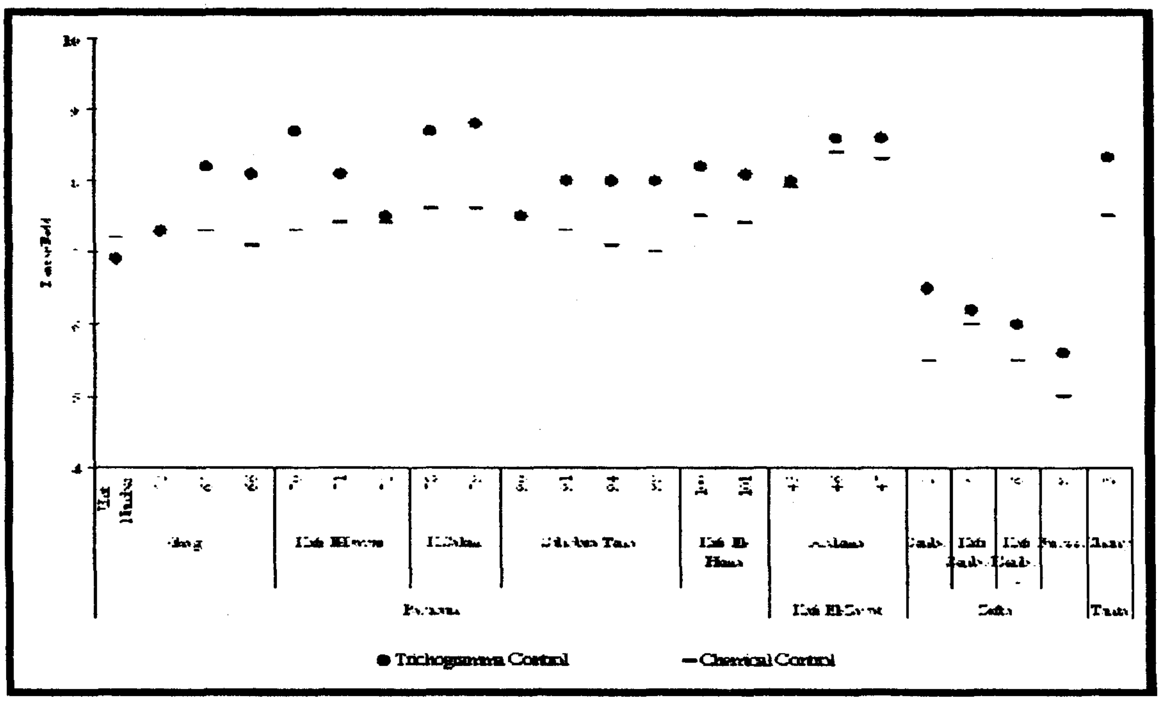


FIGURE (2): TRICHOGRAMMA VS CHEMICAL CONTROL YIELDS PER FEDDAN.



5.1.2 Crop loss

Crop loss is defined as the difference between predicted yield in absence of the cause and actual yield in presence of the cause (De Groote, 2002). However, Macharia etal, (2005) and Unlu and Bilgic (2004) argued that, the widely accepted model to measure predicted yield can be by estimating the relationship between yield and infestation ratio. Assuming a linear relationship between yield and infestation ratio, crop loss can be estimated by estimating following yield function:

$$y_i = \alpha + \beta\, ir + e_i \quad \text{.......(1)}$$

where y_i is the recorded cotton yield, α and β are parameters to be estimated, ir (explanatory variable) is the infestation ratio and e_i (disturbance term) is distributed normally with zero mean and variance σ^2.

The intercept (α) is then an estimation of the expected yield without pest, β is the change or the slope of the explanatory variable in the model. Average crop or yield loss can then be estimated by calculating the difference between α (yield at zero infestation, Y_p) and yield at the average infestation (Y_{ir}).

The above linear regression model was estimated to measure crop loss in bio and chemical control yields. For Trichogramma bio control, cotton loss is estimated via equation 2 as follows:

$$Y = 7.99 - 0.03\,ir \quad \text{.......(2)}$$

SE (0.52) (0.05)
R^2=0.70

The interpretation of that model is that cotton yield in absence of pink and spiny boll infestations can be estimated at 7.99 kentar /feddan (statistically significant at the 1% level), and this yield decreases by 0.03 kentar/feddan for each unit increase in infestation ratio. Since, the average yield was 7.74 kentar/feddan with an average infestation ratio of 9.91%, thus the average yield loss can be calculated at 0.25 kentar/feddan and expressed as a proportional crop loss at 3.1% using the following formula

$$[(Yp-Yir)/Yp) \times 100] \quad \text{.......(3)}$$

Whereas, crop loss result for chemical controlled fields is modeled as shown in equation 4:

$$Y = 8.38 - 0.08\,ir \quad \text{.......(4)}$$

SE (0.95) (0.06)
R^2=0.78

Equation 4 shows that cotton yield in absence of pink and spiny boll infestations can be estimated at 8.38 kentar/feddan (statistically significant at the 1% level), and this yield decreases by 0.08 kentar/feddan for each unit increase in infestation ratio. Considering that, the average yielded production was 7.13 kentar/feddan and the average infestation ratio 15.7%, thus the average yield loss can be calculated at 1.24 kentar/feddan and expressed as a proportional crop loss (according to equation 3) at 14.9%.

In the interest of completeness, it might be useful to estimate elasticity with respect to infestation ratio. It identifies what percentage of yield would increase (or decrease) because of percentage increase (or decrease) in infestation ratio variable. This information will play an important economic role in determining how much should be spent to remove or minimize the pests in yield. To obtain elasticity with respect to the infestation ratio at mean levels, the corresponding formula addressed in equation 5 is employed:

$$\xi_{ir} = \frac{\partial y}{\partial ir} \times \frac{\overline{ir}}{\overline{y}} \quad \text{.......(5)}$$

where, $\frac{\partial y}{\partial ir} = \beta\, ir$, $\overline{ir}$ is the infestation ratio men value and $\overline{y}$ is the yield mean value.

Elasticities of bio and chemical controlled yields are estimated at -0.03 and -0.17 respectively. This implies that, a 10% increase in pink and spiny boll infestation ratio would result a decrease in cotton yield by 0.3% for bio-controlled fields compared to 1.7% in chemical controlled fields, the result that mirrors the earlier crop loss results.

5.1.3 Costs

Trichogramma and chemical control costs reveal distinct differences in all districts. In which, chemical control costs (on average), accounts as much as twice that for Trichogramma (Figure 3A). Whereas, bio control costs is estimated at LE 81.7 per feddan (on average) compared to LE 169.8 per feddan (on average) for chemical control. Moreover, control costs were found to be statistically significant at 1% level of significance across biological and chemical control. It is worth mentioning, pesticides costs compose 64% of total chemical control costs whereas Trichogramma cost (sold in sheets) only constitutes 6.5% of total biological control (Figure 3B).

5.1.4 Benefit-Costs ratio

The average cotton price in 2005 accounted LE 700 per kentar, thus the revenues could be estimated at LE 5390 and 4994 per feddan (on average) for Trichogramma and chemical controlled fields respectively (Table 1). The highest benefit-cost ratio (3:1) have been achieved in Bassioun followed by an average 2.3:1 for Tanta and Zefta, and finally the lowest in Kafr El-Zayat (1.7:1). Moreover, the results show that the average foregone income per feddan (the difference between bio and chemical control total revenue) is estimated at LE 395.7. Therefore, the cotton sector (714,000 feddan) could have saved up to LE 282 million in 2005 if Trichogramma has been applied.

FIGURE (3A): TRICHOGRAMMA VERSUS CHEMICAL CONTROL TOTAL COSTS PER FEDDAN (ON AVERAGE).

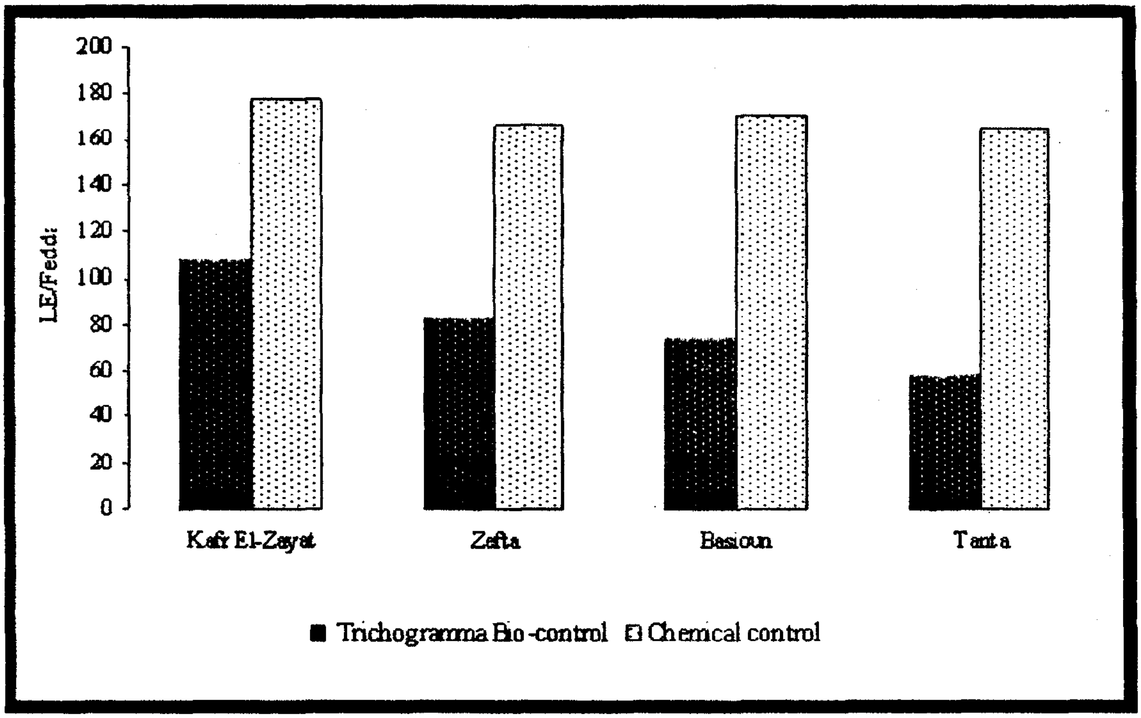


FIGURE (3B): STRUCTURE OF TRICHOGRAMMA AND CHEMICAL CONTROL COSTS PER FEDDAN (ON AVERAGE).

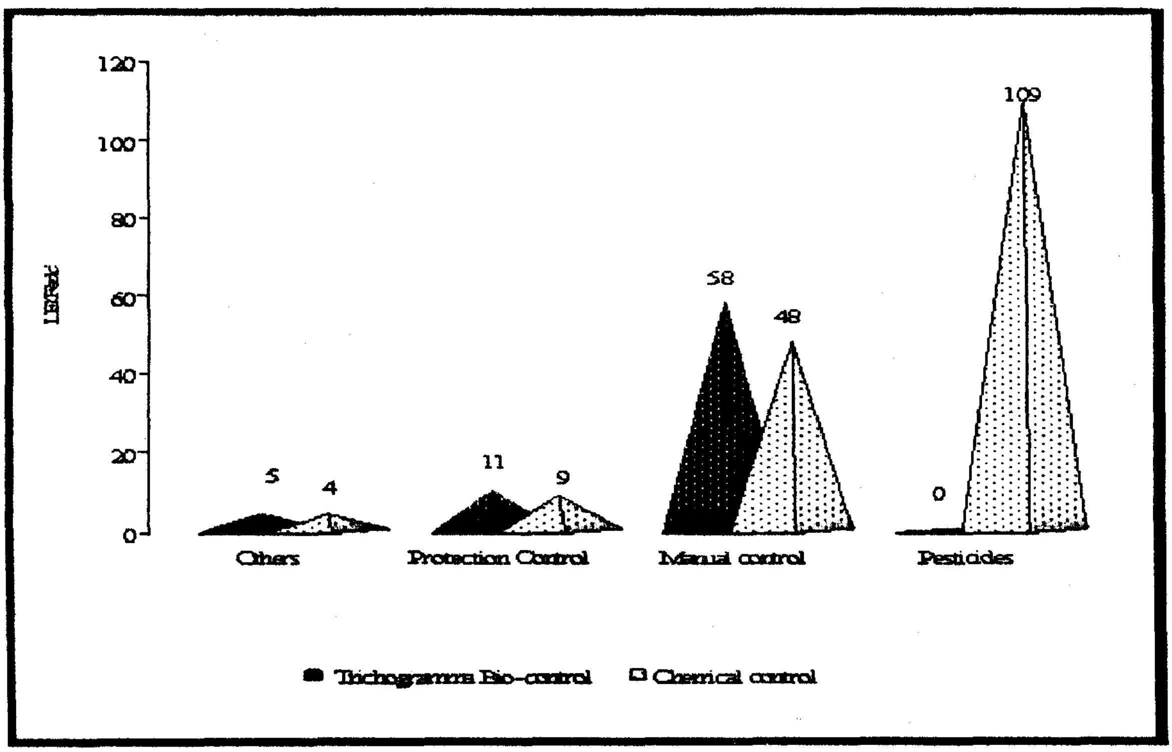


TABLE (1): FOREGONE INCOME AND BENEFIT-COST RATIO

District	Yield (Kentar/Feddan)		Gross Sale Value (Benefit) (LE/Feddan)		Foregone Income or Benefit (LE/Fed)	Control Costs (LE/Feddan)		B/C Ratio	
	Tri-Bio Control	Chem Control	Tri-Bio Control	Chem Control		Tri-Bio Control	Chem Control	Tri-Bio Control	Chem Control
Basioun	8.0	7.3	5600.0	5133.3	*466.7*	61.0	170.6	***91.8***	*30.1*
K. El-Zayat	8.4	8.2	5880.0	5740.0	*140.0*	107.7	177.6	***54.6***	*32.3*
Zefta	6.1	5.5	4270.0	3850.0	*420.0*	84.0	166.0	***50.8***	*23.2*
Tanta	8.3	7.5	5810.0	5250.0	*560.0*	74.0	165.1	***78.51***	*31.8*
Average	**7.7**	**7.1**	**5390.0**	**4994.3**	*395.7*	**81.7**	**169.8**	***66.0***	*29.4*

Source: Author calculation

Efforts to quantifying benefits to the environment in monetary terms have generally been confronted with difficulties. However, Abdel-Wahed (1972), Abdel-Gawad (1991) and Megalaa (2001) argued that the soil normally saves about 15% of chemical pesticides used, in which could last up to ten years without being decomposed; moreover, the plant could save some of those chemicals in its tissues that transfer directly to human via food or indirectly through livestock feeding. In addition, the use of aircraft in chemical control causes an air contamination with up to 50% of the used pesticide, which in turn washed by rain water and fall in seas and rivers.

The paper argues that the release of Trichogramma as an alternative to chemical pesticides resulted a fall in infestation ratios and consequently pesticides consumption, thus safer environment. Considering that, cotton receives as much as 7 kilograms per hectare of herbicide and 5 kilograms per hectare of insecticide (Gianessi and Puffer, 1990). There is no doubt, that there are additional benefits for Trichogramma biological control, such as the possibility of reduced health hazard of farmers and deaths related to pesticide use, and others concerning the reduction of externalities related to pesticide use that are more difficult to quantify. For example, problems that ranges from contamination of irrigation ditches by spraying or from washing equipment, to contamination of groundwater supplies from leaching out of pesticide, in addition to problems of resistance associated to overused pesticides that should be the subject of follow-up studies.

6.CONCLUSION

Cotton is a historical crop in the Egyptian economy in which, it is important to recognize the impact of its natural control factors and, where possible, encourage their action. This paper evaluates the potential economic and environment impacts of the introduction of Trichogramma, a parasitoid of the pink and Spiny bollworms on cotton production. However, biological control achieved a remarkable fall in terms of infestation ratio, pesticide expenditure (i.e, safer environment) and crop losses than chemical control estimated by 37.5%, 51.8% and 79.8% respectively. An average foregone yield of 0.6 kentar/feddan could be recovered, increasing the yield to 7.7 kentar/feddan (on average), in other words, saving the Egyptian cotton sector LE 282 million in 2005. For this paper calculation, an estimated crop loss of 14.9% is experienced at present. Moreover, the benefit–cost ratio for bio-controlled cotton is estimated at 66:1 compared to 29:1 for chemical controlled.

To develop and promote effective, economical and environmental acceptable control, the Ministry of Agriculture and land Reclamation have to consider the introduction and initiation of Trichogramma parasitoid bio-control programme for cotton and evaluate the indigenous natural enemies to identify specific and effective bio-control programmes

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الملخص العربى

تقييم الأثر الاقتصادى لاستخدام طفيل التريكوجراما فى المقاومة الحيوية لديدان لوز القطن القرنفلية والشوكية

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يتناول هذا البحث تقييم الأثر الاقتصادى لطفيل التريكوجراما كأحد طرق المقاومة الحيوية لكل من ديدان اللوز القنفلية والشوكية لمحصول القطن المصرى. أجريت التجربة على نطاق أربع مراكز فى محافظة الغربية (بسيون، كفر الزيات، زفتى و طنطا) و موزعة على ٤٦ حوض لتضم حوالى ١٣٠٠ فدان للموسم الزراعى ٢٠٠٥. أسفرت نتائج البحث عن التوصية بالتوسع فى استخدام التريكوجراما، و ذلك لما حققته من نسبة فقد أقل فى محصول القطن قدرت بحوالى ٣,١% فقط اذا ما قورنت بحوالى ١٥% للمقاومة الكيماوية. كما توصلت النتائج الى أن نسبة الاصابة و تكاليف المقاومة تقل فى المقاومة الحيوية عن الكيماوية بحوالى ٣٧,٥% و ٥١,٨%على التوالى. وكذا يمكن تقدير الدخل المضحى به لمنتجى القطن(لموسم ٢٠٠٥) على مستوى الجمهورية بحوالى ٢٨٢ مليون جنيه.