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BIOLOGICAL CONTROL OF TOMATO FRUITWORM IN ILOCOS[1]

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ABSTRACT

Joint efforts have been undertaken by the Philippine-German Biological Plant Protection Project, the Northern Foods Corporation, and the Cotton Research and Development Institute to develop a biological control program for *Heliothis armigera* Hubner (Lepidoptera: Noctuidae) in tomatoes as an alternative to the common chemical control practice. From 1991 to 1994, four field studies were conducted in Ilocos to determine whether inundative releases of the egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) could provide sufficient control of *H. armigera*.

Results of the studies showed that parasitism by naturally occurring populations of *T. chilonis* was an important mortality factor of *H. armigera* in Ilocos. The application of insecticides of the pyrethroid group apparently did not affect natural egg parasitism. Four to five releases of *T. chilonis* per crop at densities ranging from 450 000 to 1 000 000 *Trichogramma*/release provided results with respect to fruit quality and yield comparable to four to eight insecticide applications.

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INTRODUCTION

The Philippines produces approximately 180 000 t of tomatoes annually on a total area of around 19 000 ha. About 6 500 ha of these are planted in the two provinces of Region 1, Ilocos Norte and Ilocos Sur (Anonymous, 1994). Traditionally, tomatoes in this Region are planted after rice, from November to April. While most of the tomato area in Ilocos is planted to fresh-market varieties, about 900 ha are planted to processing varieties in contract farming for the Northern Foods Corporation (NFC), a semi-government tomato paste company based in Sarrat, Ilocos Norte.

The tomato fruitworm *Heliothis armigera* (=*Helicoverpa armigera*) Hubner (Lepidoptera: Noctuidae) is the primary insect pest of both, fresh-market and processing tomatoes grown in Ilocos. Usually, farmers control *H. armigera* by one - some even by two - applications of broadspectrum insecticides per week amounting to more than 15 applications per crop. The production guidelines of NFC for their contract growers recommend two to three applications in the tomato seedling nurseries and four to six applications in the field from the time of transplanting till harvesting.

The present chemical control practice in tomatoes is not only costly but may also result in the buildup of resistance in the insect pest population, as experienced in various other countries. Furthermore, it definitely contaminates the environment and leaves detectable levels of pesticide residues in the tomatoes and the tomato paste, a reason for the rejection of Philippine tomato paste by importing countries in the past.

In recent years, efforts have been made in many countries toward developing alternative methods of pest control in tomatoes such as biological and/or integrated control (Oatman and Platner, 1971; Bolkan and Reinert, 1994). In the Philippines, studies have been conducted from 1991 to 1994 in collaboration between the Philippine-German Biological Plant Protection Project (PGBPPP), the NFC, and the Cotton Research and Development Institute (CRDI) with the objective of developing a biological or integrated control program for *H. armigera*, also a major pest in cotton, based on the use of the egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae).

The species *T. chilonis* was chosen as the prospective biological control agent after laboratory screenings by the PGBPPP at the Bureau of Plant Industry in Manila (Unpublished Data) and similar screenings by the Biologische Bundesanstalt in Darmstadt, Germany (Wuhrer, 1993). Also, our own surveys in Ilocos prior to the *Trichogramma* studies revealed that despite the excessive use of insecticides in tomatoes, a substantial *T. chilonis* population could be found naturally parasitizing *H. armigera* eggs in the field (see below and Unpublished Data). The field trials presented here therefore aimed at increasing the natural *T. chilonis* population through releases of laboratory reared individuals at a time when they would be most effective in controlling the tomato fruitworm.

MATERIALS AND METHODS

One pretest, without *Trichogramma* releases, and three *Trichogramma* experiments were conducted in Ilocos from 1991 to 1994. The pretest and the 1st and 2nd *Trichogramma* experiment were conducted in NFC experimental areas and under NFC management, while the 3rd *Trichogramma* experiment was conducted in farmers' fields.

Tomato seedlings were grown in seed boxes and transplanted about three weeks after seeding. The seedlings received up to three insecticide (Ripcord^R, Karate^R) and fungicide (Dithane^R) treatments, respectively. Cultivars used were the processing types 'Ilocandia 4' of NFC for the pretest and the 1st and 2nd *Trichogramma* experiment and 'R1464' of NFC for the 3rd one. Amounts of fertilizer were uniform for all treatments of one experiment. Fertilizer was given in the nursery and in three split applications after transplanting at a rate of 110-150 kg N, 70 kg P_2O_5, and 150 kg K_2O. To control fungal diseases, the fungicide Dithane^R (Mancozeb) was applied five to eight times between transplanting and harvesting. Insecticides were exclusively used in the experimental plots designed to receive such treatment (see below). Plants were watered either by drip irrigation or by water hose and furrow irrigation. Harvesting of ripe tomatoes was usually done in three rounds from about 13 to 15 weeks after transplanting.

T. chilonis was reared by the PGBPPP in Manila. The parasitoids were glued as pupae in *Sitotroga* sp. eggs on card board frames, called

Trichocards, each of which carried 1 500 to 2 000 *Trichogramma*. To avoid predation of *Trichogramma* mainly by ants, the Trichocards were attached to 50 cm long bamboo sticks the bases of which were coated with insect chalk. The sticks were posted in the ground along the tomato rows in a certain pattern, slightly varying from experiment to experiment, and served as *Trichogramma* release posts throughout the release period of each experiment.

As *Trichogramma* wasps, once emerged, cannot be confined to the plot where they were released, experimental plots in *Trichogramma* field studies should be rather big to avoid severe dilution of the released *Trichogramma* population through dispersal to neighboring plots. For the same reason, plots adjacent *Trichogramma* release plots should not be used for comparative treatments. Treatment effects in adjacent plots would be biased by the influence of *Trichogramma*. The size of the experimental plots or farmers' fields where *Trichogramma* were released ranged from 600 to 1 600 m^2. The *Trichogramma* plots were separated from the plots that received chemical or no treatment by at least 50 m. In some experiments we additionally planted several corn rows alongside the *Trichogramma* plots to further reduce the dispersal of *Trichogramma*. The sizes of the plots used for other experimental treatments ranged from 300 to 950 m^2. As land resources available for our experiments were limited, the treatments of our experiments were not repeated, except for the 3rd *Trichogramma* experiment, in which all treatments were replicated.

Monitoring of *Heliothis* egg population and egg parasitism in the experiments started one to two weeks after transplanting. Per plot, 50 or 100 plants were selected following a diagonal cross sampling pattern and examined for the number of *Heliothis* eggs. Eggs were considered parasitized if black in color. White or cream colored eggs were recorded as unparasitized. Computation of egg parasitism was based on the percentage of black eggs in the field. When the examination of 50 or 100 plants/plot did not yield at least ten *Heliothis* eggs, which often was the case shortly after transplanting and before harvesting, more tomato plants were randomly sampled for additional eggs until at least ten eggs were found. These eggs were recorded separately and used only for determining the percentage of egg parasitism.

To measure the tomato fruitworm damage and the tomato yield, the numbers and weights of undamaged fruits and fruits damaged by *Heliothis* per plot were recorded at harvest. In the pretest and the 1st *Trichogramma* experiment, yield samples were taken from two blocks of 8 m x 8 m, amounting to 128 m^2/plot. In the 2nd and 3rd *Trichogramma* experiment, three blocks of 5 m x 3 tomato rows were sampled in each plot. Depending on the row distances in the experiments, the total sample areas of the three blocks summed up to 35 to 45 m^2/plot.

Pretest. To gather some information on the oviposition pattern of *H. armigera*, on natural egg parasitism, and the effect of insecticide treatments on *H. armigera* and naturally occurring *T. chilonis*, the pretest was conducted in Batac, Ilocos Norte.

The following two treatments were compared.
(1) insecticide treatment following NFC practice,
(2) control with no insecticide treatment.

Seedlings for the pretest were transplanted at a density of about 31 000 plants/ha on 2 January and the harvest was completed by 24 April 1992. The insecticide treatment consisted of six applications of alternatively Karate[R] (Cyhaluthrin), Cymbush[R] (Cypermethrin) or Ripcord[R] (Cypermethrin) in the recommended dosages after transplanting. The plot size was about 950 m^2 for both treatments.

1st *Trichogramma* Experiment. The seedlings for the 1st *Trichogramma* experiment were transplanted in Batac, Ilocos Norte on 19 January, and tomato harvest was completed by 17 April 1993. Plant density was approximately 31 000 plants/ha and plot sizes were 1 600 m^2 for the *Trichogramma* and 900 - 950 m^2 for the other treatments.

The effects of the following four treatments were compared:
(1) *Trichogramma* releases, one age,
(2) *Trichogramma* releases, mixed age,
(3) insecticide treatment,
(4) control with no insecticide treatment.

Trichogramma in both *Trichogramma* treatments were released four times in weekly intervals starting 15 days after transplanting. The Trichocards were distributed in the plots at a distance of 10 m along x 3.2 m across the rows, equaling a release density of 310 Trichocards/ha or 465 000 - 620 000 *Trichogramma*/ha. In treatment 1, the *Trichogramma* pupae brought to the field on the Trichocards were all of the same age and the wasps were therefore timed to emerge mostly within one day. In treatment 2, however, the Trichocards were supplied with *Trichogramma* of several developmental stages and the parasitoid wasps were timed to emerge within a period of one to seven days. Corresponding to the short emergence period of the *Trichogramma* wasps in treatment 1, the main parasitization of *Heliothis* eggs in the field was expected to peak within one to two days of the release week. In contrast, parasitization of *Heliothis* eggs in treatment 2 was expected to take place uniformly throughout the release week.

To compare the effect of the two *Trichogramma* release modes was one objective of the 1st *Trichogramma* experiment. The other objective was to compare the effect of *Trichogramma* treatments to chemical or no insect control. The insecticide treatment in this experiment was identical with the one in the pretest.

2nd *Trichogramma* Experiment. The seedlings for the 2nd *Trichogramma* experiment were transplanted in Cabugao, Ilocos Sur, on 28 December 1993 and tomato harvest was completed by 19 April 1994. Plant density in this experiment was about 25 000 plants/ha.

The experiment consisted of three treatments:
(1) *Trichogramma* releases,
(2) insecticide treatment,
(3) control with no insecticide treatment.

The experimental treatments were replicated twice. The plot size for the two replications of the *Trichogramma* treatment was 600 m², for the insecticide treatment it was 300 and 600 m² for the 1st and 2nd replication, respectively, and the two control plots measured 230 m² each.

In treatment 1, *Trichogramma* were released five times in weekly intervals starting 14 days after transplanting at a release density of 750 000 - 1 000 000 *Trichogramma*/ha (i. e. 500 Trichocards/ha, release distance 10 m along x 2 m across the rows). Consequent to the result of the

1st *Trichogramma* experiment, *Trichogramma* on the Trichocards were of different developmental stages in this and the 3rd *Trichogramma* experiment. In the insecticide treatment, a total of four rounds of Decis[R] (Decamethrin) and Karate [R] were applied alternately in intervals of one to two weeks after transplanting.

3rd *Trichogramma* Experiment. To get more examples of the effect of *Trichogramma* releases in comparison to the common insecticide practice, the 3rd *Trichogramma* experiment was conducted in three farmers' fields during the same season as the 2nd *Trichogramma* experiment. As an additional experiment component, *Trichogramma* releases were combined in one site with the application of the microbial insecticide *Bacillus thuringiensis* (*B.t.*) Berl. which is known for its compatibility with *Trichogramma* as well as with other insect parasitoids (Hassan *et al.* 1987). The heterogeneity of the three different sites allowed comparisons only of two treatments each at one site. The three sites were located in Tabug, Baoa West, and Noto, all in Ilocos Norte.

In the three sites, treatments were compared as follows:
(1) *Trichogramma* releases with insecticide treatment in Tabug,
(2) *Trichogramma* releases and *B.t.* applications with insecticide treatment in Baoa West,
(3) no insecticide treatment with insecticide treatment in Noto.

In Tabug, tomato seedlings were transplanted on 10 January 1994 at a density of approximately 38 000 plants/ha. Harvesting was completed by 19 April 1994. Plot sizes were about 700 m² for the *Trichogramma* and 300 m² for the insecticide treatment. In the *Trichogramma* treatment, five releases of 715 000 - 950 000 *Trichogramma*/ha (i. e. 475 Trichocards/ha) were made beginning eight days after transplanting. Trichocards were placed at a release distance of 10 m along x 2.1 m across the rows. In the insecticide treatment, Decis[R] and Karate[R] were applied four times alternately.

In Baoa West, tomato seedlings were transplanted at a density of about 36 000 plants/ha on 9 January and the harvest was completed by 19 April 1994. Plot sizes were the same as in Tabug. Five releases of 625 000 - 835 000 *Trichogramma*/ha (i. e. 415 Trichocards/ha, release distance

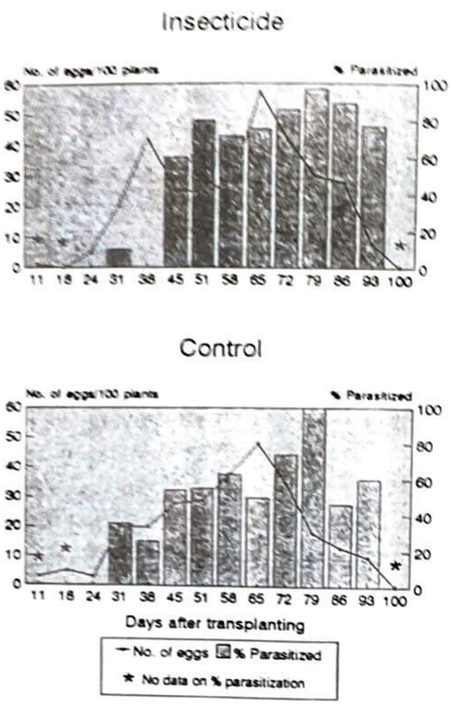

Fig. 1: Parasitization of *Heliothis* eggs in an insecticide treated and in an untreated tomato field (Pretest, Batac, December 1991 - April 1992)

10 m along x 2.4 m across the rows) were made beginning ten days after transplanting. Additionally, *B.t.* (Thuricide[R]) was applied six times in weekly intervals after transplanting. To improve its adhesion to the plants, 10 ml sticker (Hoestick[R]) were added to 16 l of *B.t.* spray solution. In the insecticide treatment, Decis[R] was applied three times and Azodrin[R] (Monocrotophos) two times after transplanting.

In Noto, the insecticide treatment consisted of eight applications of alternately Karate[R] and Decis[R]. Plot sizes were 200 m² for the control and 400 m² for the insecticide plot. Transplanting was done on 25 December 1993 at a density of 38 000 plants/ha and harvesting was completed by 4 April 1994.

RESULTS AND DISCUSSION

The oviposition patterns of *H. armigera* in the various experiments are demonstrated in Figures 1, 2, 3, and 4. The same figures also show the development of egg parasitism in the experiments without any insecticide treatment and under the influence of chemical insect control, or of *T. chilonis* releases. During the early and late sampling dates, the percentage of parasitism could not always be obtained because it was not possible to find the minimum number of eggs required to define the percentage. In Table 1, mean rates of parasitism of *Heliothis* eggs are presented for all experiments. Table 2 summarizes the results derived from the yield samples of each experiment taken at harvest.

Natural Egg Parasitism of *H. armigera*. The results of oviposition monitoring in all experiments showed that egg laying of *H. armigera* typically starts around one week after transplanting, when the seedlings have recovered from the transplanting shock, reaches a peak during flowering and fruiting stage from 35 to 75 days after transplanting, and ends between 85 to 100 days after transplanting (Fig. 1, 2, 3, 4).

Parasitization of *Heliothis* eggs also began shortly after transplanting, as can be seen in the control plots of the experiments. Egg parasitism in the untreated control plots of the 2nd and 3rd *Trichogramma* experiment, for example, reached more than 40 and 50 %, respectively, at 13 to 14 days after transplanting, indicating that parasitization has started right when the first *Heliothis* eggs were laid or even while the seedlings were still in the seed boxes. Natural parasitism in the control plots usually was low during the first few weeks after transplanting, but reached up to 100% during the later crop stages (Fig. 1, 2, 3, 4). During nine to eleven weeks of weekly monitoring in our experiments, average natural egg parasitism of *H. armigera* ranged from 51 to 77 % (Table 1). The predominant species parasitizing *H. armigera* was identified as *T. chilonis*. It was surprising to find such high natural egg parasitism, as Marcos & Rejesus (1992) did not report about egg parasitism in their study on *H. armigera* and *Heliothis assulta* Guenee conducted in the same area.

Our results indicate that parasitism by naturally occurring populations of *T. chilonis* is an important mortality factor of *H. armigera*

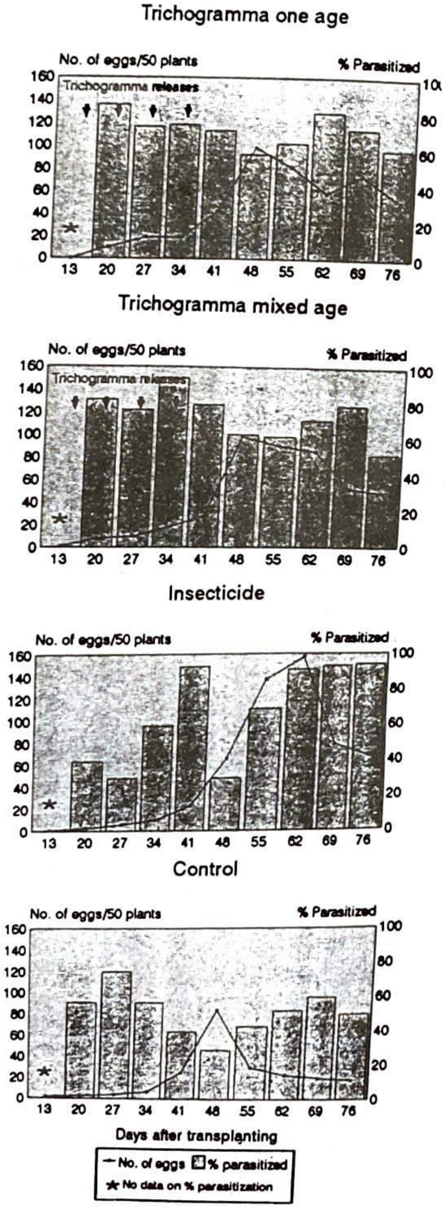

Fig. 2: Parasitization of *Heliothis* eggs in the 1st *Trichogramma* experiment (Batac, January - April 1993)

in Ilocos and should therefore be definitely considered in any control program for *H. armigera*.

Influence of Insecticide Treatments on Natural Egg Parasitism. Several authors have demonstrated the adverse effect of synthetic insecticide sprayings in tomato on egg parasitism by *Trichogramma* spp. (Oatman *et al.* 1983, Roltsch and Mayse, 1983). Hoffman *et al.* (1990) reported a decrease of *Heliothis zea* Boddie egg parasitism by *Trichogramma* spp. by nearly 50 % in processing tomatoes in California through the use of Fenvalerate, Methomyl, and Carbaryl. In Portugal, egg parasitism of *H. armigera* fell from 80 to 18% through excessive insecticide use (Meterrose and Araujo, 1986). Consonant with these findings, egg parasitism in the insecticide plots of our experiments was distinctly lower than in the corresponding untreated control plots from the beginning of monitoring up to 38, 27, and 21 days after transplanting in the pretest, the 1st and 2nd *Trichogramma* experiment, and the 3rd *Trichogramma* experiment, respectively. After the initial knock-down of the naturally occurring field populations, *T. chilonis* populations in the insecticide plots seemed to recover, however, such that egg parasitism in the insecticide plots was even higher than in the control plots in the pretest and 1st *Trichogramma* experiment, about the same in both treatments in the 2nd *Trichogramma* experiment, and only slightly lower in the insecticide than in the control plot in Noto in the 3rd *Trichogramma* experiment (Fig. 1, 2, 3, 4).

The mean rates of parasitism in the insecticide and control plots of our experiments, as shown in Table 1, reflected the same result. Overall parasitism in the insecticide plots was slightly to distinctly higher in the pretest, 1st and 2nd *Trichogramma* experiment and only slightly lower than in the control plot in the 3rd *Trichogramma* experiment. The application of *B.t.* in the 3rd *Trichogramma* experiment seemed to have had no negative effect on egg parasitism in the *Trichogramma* release plot.

The results obtained in the insecticide plots were surprising because examples from other countries, as mentioned above, showed rather the opposite effect of insecticide treatments on *Trichogramma* populations. Apparently, the insecticides used in our experiments had some negative influence on *T. chilonis* when the tomato plants were still small and so did not offer much hiding space to the *Trichogramma* wasps. But in the later

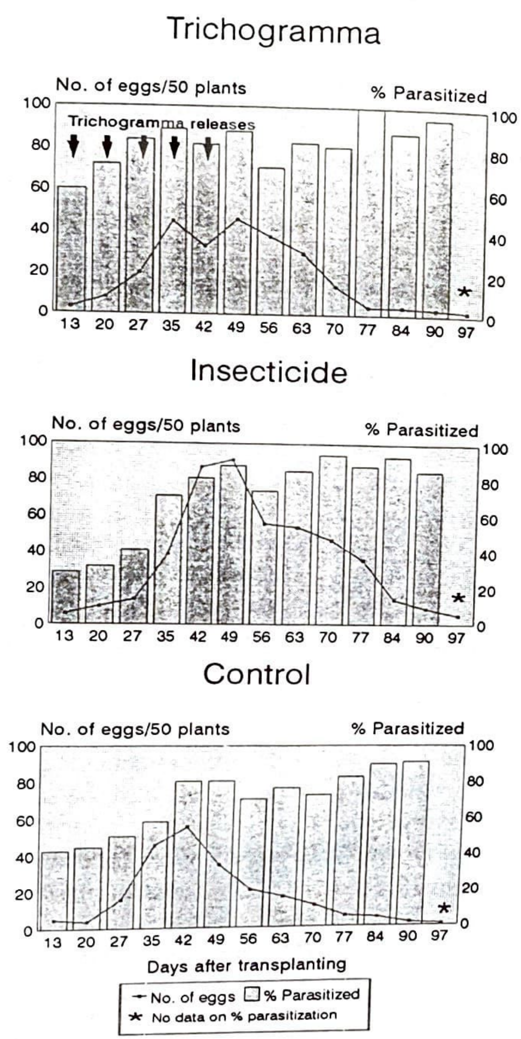

Fig. 3: Parasitization of *Heliothis* eggs in the 2nd *Trichogramma* experiment (Cabugao, December 1993 - April 1994. Means of 2 fields/treatment.)

crop stages, when the canopy was more voluminous, the parasitoids could probably find enough shelter so that they were no longer affected by sprayings.

The results may also hint to an insecticide tolerance of the field populations of *T. chilonis* found in Ilocos. The insecticides used in our experiments were mostly pyrethroids. In tests conducted by Hassan *et al.* (1987), pyrethroids commonly used in vegetable crops were demonstrated to be slightly less toxic to adult *Trichogramma* than insecticides of the organophosphate or carbamate groups. Yet pyrethroids were still listed as harmful to the susceptible life stages of *Trichogramma*.

The clarification of whether *Trichogramma* populations tolerant or resistant to pyrethroids exist in Ilocos tomato fields is a very important task for the future. The fact of insecticide-tolerance or -resistance of field populations of *Trichogramma* would then have to be considered in any decision concerning an integrated control program for *H. armigera*.

Effect of *Trichogramma* Releases on *Heliothis* Egg Parasitism. Releases of laboratory reared *T. chilonis* clearly increased the egg parasitism of *H. armigera* in all *Trichogramma* experiments. The difference to the corresponding control and insecticide plots was at its extreme specifically during the early crop stages, when parasitism due to naturally occurring *Trichogramma* populations was still low (Fig. 2, 3, 4). Because of the high natural parasitization, however, no clear differences between the various treatments were visible during the later crop stages. Overall parasitism, as presented in Table 1, was consistently higher in all experiments in the *Trichogramma* treatments than in the control or insecticide treatments.

Larvae emerging from unparasitized eggs laid during the early crop stages are usually complete their entire life cycle in the crop and therefore cause more fruit damage than larvae emerging from eggs laid subsequently, when the remaining time before harvest is too to short to allow them to develop into the devastating 4th or 5th instar larvae. A high egg parasitism in the early crop stages, as achieved by *Trichogramma* releases in our experiments, is therefore expected to have a strong influence on damage reduction.

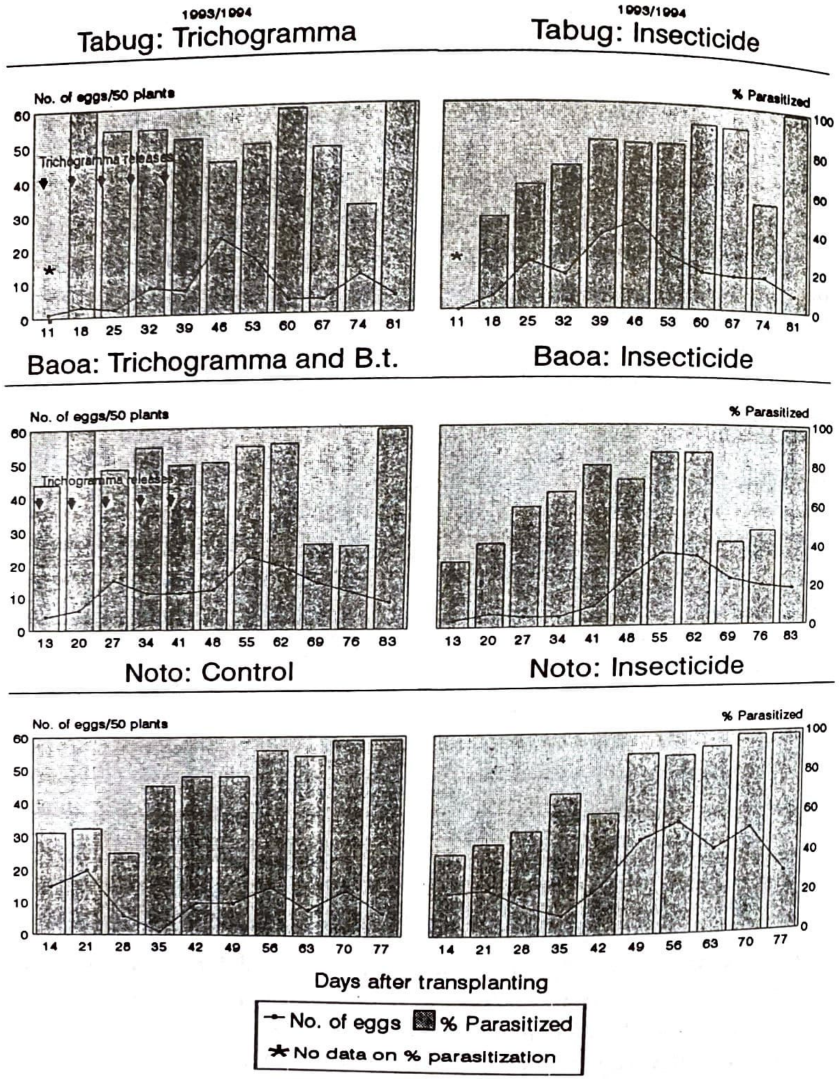

Fig. 4 Parasitization of *Heliothis* eggs in the 3rd *Trichogramma* experiment (Tabug, Baoa West and Noto, December 1993 - April 1994)

Trichogramma was released four to five times in weekly intervals in our experiments. Results of the monitoring showed that high parasitization rates already occurred after two to three releases. The fourth and fifth releases did not produce any distinctly higher parasitization rates. For future experiments and also for practical purposes, it is therefore recommended to release *Trichogramma* only two to three times in weekly intervals.

Moreover, the quantity of *Trichogramma* per release used in our experiments was very high. Release quantities ranged from 310 Trichocards/ha (i. e. 465 000-620 000 *Trichogramma*/ha) in the 1st *Trichogramma* experiment to 500 Trichocards/ha (i. e. 750 000-1 000 000 *Trichogramma*/ha) in the 2nd, without any clear difference. In comparison, weekly releases of 750 000 *Trichogramma pretiosum* Riley/ha are recommended for the control of *Heliothis zea* Boddie in Mexico (Bolkan and Reinert, 1994), and around 100 000 *T. pretiosum*/ha /release in California (Oatman and Platner, 1971).

As shown in Figure 2 and Table 1, none of the two different modes of releasing *Trichogramma*, either in a single developmental stage or as a mixture of different developmental stages, was clearly superior to the other. Since we reckoned that the second mode had some advantages over the first one due to the homogeneity of the *Trichogramma* emergence and parasitization, we continued using mixed developmental stages of *Trichogramma* for the later experiments. Using that mode of *Trichogramma* releases, it must be ensured, however, that the Trichocards are protected against predation.

Trichocards was placed in every second tomato row in the 1st and 2nd *Trichogramma* experiment and in every third row in the 3rd one. The distance between two release points within one tomato row was 10 m all throughout. This release pattern was chosen as *Trichogramma* wasps are known to disperse more easily along the rows than across the rows. It may be possible to further reduce the number of *T. chilonis* per release to a number lesser than the tested quantities without diminishing the control effect on *H. armigera*. But it might be better to do so by reducing the number of *Trichogramma* on the Trichocards rather than by reducing the number of release points/ha. In any case, further studies are needed to determine the optimum number of *T. chilonis* required for a more economical control of *H. armigera*.

Table 1: Mean parasitism of *Heliothis* eggs in pretest and *Trichogramma*-experiments (1991/92-1993/94)

Experiment	Treatment	No. of samplings (sampling period)	Mean rate of parasitization (in %)
Pretest 1991/92	Insecticide	11	**59**
	Control	11	**51**
		(24-100 DAT)	
1st Exp. 1993	*Tricho*, one age	9	**71**
	Tricho, mixed age	9	**73**
	Insecticide	9	**67**
	Control	9	**51**
		(20-76 DAT)	
2nd Exp. 1993/94	*Trichogramma*	12	**83**
	Insecticide	12	**72**
	Control	12	**70**
		(13-90 DAT)	
3rd Exp. 1993/94	*Trichogramma*	10	**85**
	Insecticide	10	**76**
		(18-81 DAT)	
	Tricho + *B.t.*	11	**80**
	Insecticide	11	**65**
		(13-83 DAT)	
	Insecticide	10	**74**
	Control	10	**77**
		(14-77 DAT)	

DAT - Days after transplanting

Yield and Fruit Quality at Harvest. The individual yield components of the pretest and the *Trichogramma* experiment are summarized in Table 2. In all experiments, the highest total yields were realized either by *Trichogramma* releases or by insecticide applications, no treatment being distinctly better than the other one. Both methods of controlling *H. armigera* guaranteed certainly higher yields than in the plots where *H. armigera* was not controlled. Also, after deducting the fruits that were damaged by *Heliothis*, and computing the relative yield using the yield obtained with the common practice of insecticide applications as a reference yield, *Trichogramma* releases proved to secure the same yields as insecticide treatments. Relative yields in the *Trichogramma* plots ranged from 90 to 111 %.

Table 2: Yield and fruit quality at harvest in pretest and *Trichogramma*-experiments (1991/92-1993/94)

Experiment	Treatment	Tot. no. of fruits/ha x 1000	Tomato yield		
			Total in t/ha	% dam. fruit weight	Rel. Yield[1] of undam. fruits (in %)
Pretest 1991/92	Insecticide	2 096	51.3	7.9	**100**
	Control	875	26.2	22.5	**43**
1st Exp. 1993	*Tricho*,one age	701	22.8	2.7	**111**
	Tricho,mixed	613	19.2	2.3	**94**
	Insecticide	680	20.4	1.8	**100**
	Control	509	15.3	3.9	**74**
2nd Exp. 1993/94	*Trichogramma*	1 441 ±278	49.5 ±8.7	3.1	**90**
	Insecticide	1 559 ±116	54.8 ±8.7	2.1	**100**
	Control	1 220 ± 98	39.7 ±4.7	5.1	**70**
3rd Exp. 1993/94	*Trichogramma*	1 589	36.3	2.0	**104**
	Insecticide	1 601	35.2	2.7	**100**
	Tricho + *B.t.*	839	23.8	4.7	**100**
	Insecticide	827	24.1	5.2	**100**
	Insecticide	1 478	48.6	1.7	**100**
	Control	658	18.7	12.8	**34**

1) Rel. yield with reference to the respective Insecticide Treatments in each experiment.

In Baoa West in the 3rd *Trichogramma* experiment, complementary applications of *B.t.* did not reflect in a higher yield (Table 2). This was to be expected as the *Trichogramma* releases alone already ensured a sufficient *Heliothis* control (Fig. 4) to obtain a 100 % relative yield and the applications of *B.t.* could not improve this result further.

Considering the harvest data, it may be lastly stated that the method of controlling *H. armigera* with releases of *T. chilonis* can compete with the common practice of chemical control.

SUMMARY

The results of our experiments may be summarized as follows:

1. Parasitism by naturally occurring populations of *T. chilonis* was an important mortality factor of *H. armigera* in Ilocos and thus has to be considered in all future *Heliothis* management programs.

2. Applications of pyrethroids apparently harmed naturally occurring *T. chilonis* populations only when the tomato crop was still young and the canopy was not yet fully developed. In some fields, natural parasitism in the later crop stages was even higher in the insecticide than in the control plots, hinting at the existence of an insecticide tolerant *T. chilonis* population in Ilocos.

3. Four to five releases of *T. chilonis* at densities ranging from 450 000 to 1 000 000 *Trichogramma*/ha distinctly increased egg parasitism in the early crop stages, during which naturally occurring parasitism was still low.

4. Similar results with respect to fruit quality and yield were obtained with the common practice of four to eight insecticide applications and the method of four to five releases of *T. chilonis*. The same yield level was also realized with a combination of *Trichogramma* releases and *B.t.* applications as with five synthetic insecticide applications. Both methods, that of *Trichogramma* releases as well as chemical insect control, ensured much higher yields than that obtained from untreated control plots.

CONCLUSIONS AND RECOMMENDATIONS

The results of the studies presented clearly show, that a comparable result regarding fruit quality and yield can be obtained with *T. chilonis* releases as with synthetic insecticide treatments. The *Trichogramma* quantities/release tested proved to have been very high and can surely be reduced without any detrimental effect on the *H. armigera* control. Also, the number of *Trichogramma* releases/crop could probably be reduced to two to three releases of *Trichogramma* in weekly intervals starting at about eight to ten days after transplanting. Additional studies need to be conducted to determine the optimum number of *T. chilonis* required for a more economical control of *H. armigera*.

Although in our example additional applications of the microbial insecticide *B.t.* did not further improve the result due to the high quantities of released *Trichogramma*, it is nevertheless suggested that more studies be conducted on how to integrate *B.t.* in a biological or integrated control program for *H. armigera*. As *B.t.* is not toxic to *Trichogramma*, it can be excellently combined with *Trichogramma* releases in cases where other lepidopterous pests become more abundant and need additional control measures, or where *Heliothis* larvae emerged from unparasitized eggs need additional control.

Both approaches to manage *H. armigera*, either its control with inundative releases of *T. chilonis* or with *B.t.*, or a combination of the two methods, offer great advantages compared to the present common practice of using synthetic insecticides. The practices are absolutely non-toxic to the farmers and they neither leave any harmful residues in the produce nor in the environment.

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