INUNDATIVE RELEASES OF *TRICHOGRAMMA EVANESCENS* (WESTW.) TO CONTROL ASIAN CORN BORER IN THE PHILIPPINES[1]

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INTRODUCTION

In search for non-chemical methods to control Asian corn borer, *Ostrinia furnacalis* GUENEE (Lepidoptera: Pyralidae), a major pest of corn in the Philippines, the importation and rearing of the parasitoid wasp *Trichogramma evanescens* WESTW. (Hymenoptera: Trichogrammatidae) was initiated in 1982 by the Philippine-German Crop Protection Programme at the Bureau of Plant Industry (BPI) in Manila. The first inundative releases in 1983 showed promise, with further trials attaining egg parasitization of up to 90% and corn borer damage reduction of up to 71% (TRAN & HASSAN 1986). Consequent to this, the mass-production and field releases of *T. evanescens* were intensified beginning in 1988 under the Philippine-German Biological Plant Protection Project (PGBPPP). Field releases

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in the major corn producing areas of the Philippines increased from approximately 3000 ha in 1988 (FELKL 1989) to more than 14 000 ha in 1992 (TEAÑO et al. 1994).

Aside from the dramatic increase in Trichogramma production and field release in the past years, a substantial change in natural mortality of Asian corn borer eggs has occurred as a result of the initial releases of *T. evanescens*. Natural parasitization of Asian corn borer egg masses was reported to have been extremely low prior to releases of *T. evanescens* (CAMARAO 1976). PANTUA et al. (1976) failed to find any egg parasitoids in Laguna and Batangas provinces. Moreover, more than 2000 Asian corn borer egg masses collected in 1984 and 1985 in Laguna and incubated until black head stage did not yield any egg parasitoid (FELKL 1986). Similarly, none was found in Mindanao corn areas in 1984 by HASSAN (1987).

In 1986, however, first reports were made on the establishment of *T. evanescens* in Mindanao corn areas (TRAN et al. 1986). From 1988 to 1990 recovery studies showed that *T. evanescens* was well established in four major corn areas of the Philippines, namely in Cagayan Valley (Region 2), Bukidnon (Region 10), Davao del Sur (Region 11) and Sultan Kudarat (Region 12) (FELKL et al. 1991, 1992). Without further releases of *T. evanescens* in these areas, maximum parasitization levels of up to 100% and average levels of up to 77% were reached during silking stage of corn plant development. In three consecutive cropping seasons parasitism remained at similar levels, thus allowing the conclusion that *T. evanescens* populations were permanently established. Since *T. evanescens* was never considered an indigenous parasitoid in the Philippines, the presently existing high parasitization rates may be attributed to its recent introduction.

Typical also for other examples of host-parasitoid relationships, results of the recovery studies by FELKL et al. (1991, 1992) showed that in a newly planted corn field where the corn borer population is only beginning to build up, several generations of *T. evanescens* are necessary to reach a Trichogramma population that could sufficiently suppress *O. furnacalis*. Therefore a considerable portion of the initial corn borer egg population in each field usually escapes parasitization by established Trichogramma populations.

For farmers growing corn on a low input level, the reduction of corn borer damage by established Trichogramma populations may be enough to warrant stopping insecticide use. If the damage arising from early laid, unparasitized corn borer eggs is intolerable, as in farmers' fields with high inputs, inundative releases of *T. evanescens* should be attempted to boost Trichogramma populations at the beginning of corn borer oviposition.

Previous recommendations for the use of Trichogramma were based on experiences in corn fields without established Trichogramma populations. Therefore studies on inundative releases of *T. evanescens* were conducted to adjust and verify recommendations for the use of Trichogramma in corn areas with well established Trichogramma populations.

This paper presents findings of these studies which were conducted during the 1990/91 and 1991/92 cropping seasons, and discusses and summarizes the presently advocated recommendations of the PGBPPP for the use of *T. evanescens* in corn. It also expounds on the economical benefits of the use of Trichogramma in comparison to insecticide applications.

METHODS

Experimentation

To obtain maximum homogeneity of the fields used in the on-farm trials, farmers were requested to use hybrid seeds, the same quantity and kind of fertilizer and the same between and within row spacing in one study.

T. evanescens was brought to the field in form of card board cards, called Trichocards, each of which carried 1500 to 2000 Trichogramma. To avoid predation of Trichogramma, Trichocards were brought to the field either one day before or on the day of Trichogramma emergence.

Except for one case, Trichogramma were always released twice. The first release was made at 28 to 30 days after planting, the second at 35 to 37 days after planting, i.e., one week later.

In addition to monitoring corn borer egg mass parasitization, 100 plants per field were dissected one week before harvest to determine the number of corn borer tunnels. 200 plants per study field were used to determine the grain yield. Sample plants were chosen following a stratified sampling pattern.

1990/91 studies

In the 1990/91 studies different release densities of *T. evanescens* and frequencies of releases were compared in three study areas, namely in Bangcud and Nabag-O, Bukidnon (Region 10) and in Malagos, Davao del Sur (Region 11). Trichogramma releases were made at densities of 50 Trichocards/ha/release (i.e., equivalent to 75 000 to 100 000 Trichogramma/ha) or 100 cards/ha/release (i.e., equivalent to 150 000 to 200 000 Trichogramma/ha). Except for one case, *T. evanescens* was released in two batches at a week's interval. In each study area, the Trichogramma fields had a corresponding control field which did not receive any Trichogramma or insecticide treatment. For the various treatments at each study area see Table 1.

In each study area, a large, rectangular field of 2.5 to 3 ha in size was divided into four plots as follows: two plots of approximately 0.5 ha size to accommodate the Trichogramma treatments, one plot of 0.5 ha size for the control treatment and another plot, i.e., the rest of the field, to serve as a buffer zone of at least 50 m width between the Trichogramma and control plots. All study treatments were repeated in a similarly large field in the same area.

1991/92 studies

As a consequence of results of the 1990/91 studies only one Trichogramma release density, i.e., 70 Trichocards or 105 000 to 140 000 Trichogramma/ha in two releases per field, was tested in 1991/92 in Isabela (Region 2) and South Cotabato (Region 12).

To ensure against any influence of plot size or of dispersal of Trichogramma from the release plots to neighboring plots on the studies' results two solid corn areas of 10 to 14 ha each and of equal quality were selected in each study site. Both areas in one study site consisted of several fields all planted within one week. One of the two areas served as control area receiving no treatment, while the other, which was located at least 1.5 km away from the control area, served as Trichogramma release area. In each area, six core fields of approximately 1 ha each were selected as sample fields.

RESULTS AND DISCUSSION

Quantity and timing of Trichogramma releases

Results of the 1990/91 studies are summarized in Table 1. A comparison of the effect of one or two applications of Trichogramma/season in Nabag-O, Bukidnon shows that two applications clearly gave better results. Corn borer damage was reduced by 33% following the application of 2 x 50 Trichocards/ha whereas it was reduced only by 17% following the application of 1 x 50 Trichocards/ha. Consequently, relative yields of 120% and 109% were harvested from fields treated with two and one application of Trichogramma, respectively, as compared to untreated fields (Table 1).

Table 1. Effect of different release quantities of *T. evanescens* on Asian corn borer damage and corn yield (1990/91 Studies)

Location and year	Trichogramma releases[1)]	-Corn borer damage- No. of tunnels/ 100 pl.	Damage reduct. in%	-------Corn yield ------ Grain yield (t/ha)	Rel. yield (%)	Yield loss red.(%)
Nabag-O Bukidnon Region 10 1990	2 x 50 cards	93	33	4.32	122	\
	1 x 50 cards	116	17	3.99	112	/
	no release	140		3.55	100	15
Malagos Davao d.S. Region 11 1990/91	2 x 100 cards	56	27	5.52	115	\
	2 x 50 cards	59	23	5.32	111	/
	no release	77		4.81	100	11
Bangcud Bukidnon Region 10 1990/91	2 x 100 cards	79	44	5.94	120	\
	2 x 50 cards	88	37	5.39	109	/
	no release	140		3.55	100	13

1) Mean of 2 replications (fields) of each treatment.

A major factor influencing the successful control of corn borer using Trichogramma is the timely application of Trichogramma. In a best case scenario, Trichogramma wasps are already in the corn field when the first corn borer eggs are laid so that no eggs can escape parasitization. This is important because larvae developing from eggs laid at an early stage of corn plant development can cause considerable damage (JARVIS et al. 1961, HUA 1966, FELKL 1986).

Typically, egg deposition of *O. furnacalis* in the Philippines begins three to four weeks after planting (CALORA et al. 1965, HASSE 1981, FELKL 1986, KUGEL 1994), however, actual oviposition patterns vary from field to field. To avoid any risk of missing the best time for Trichogramma release in an individual field, two releases of Trichogramma within a one-week interval are strongly recommended, with the first release being made four weeks after planting.

As can be seen in Table 1 the principle of "more is better" applies not only for the number of Trichogramma applications but also for the quantity of Trichogramma per application. In both study areas, in Malagos, Davao del Sur and Bangcud, Bukidnon releases of 2 x 100 Trichocards/ha (150 000 - 200 000 wasps/ha) resulted in lower corn borer damages and higher yields than releases of 2 x 50 Trichocards/ha (75 000 - 100 000 wasps/ha). The differences, however, were by far not proportional to the differences in Trichogramma quantities. A change in damage reduction from 37% to 44% in Bangcud and from 23% to 27% in Malagos was induced by doubling the quantity of Trichocards/release from 50 cards to 100 cards (Table 1).

In both study areas, relative corn yields were highest in the treatments using the highest quantities of Trichogramma (Table 1). However, in Bukidnon, under a higher corn borer infestation pressure than in Davao del Sur, nearly the same relative yields of 120% and 122% were obtained by releasing 2 x 50 Trichocards/ha in Nabag-O and 2 x 100 Trichocards/ha in Bangcud, respectively.

Results of the 1990/91 and previous studies tend to show that to a limited extent, damage and yield loss can be further reduced by increasing the number of Trichogramma/release from 75 000 - 100 000 Trichogramma/ha to 150 000 - 200 000. The decision as to how many Trichocards to use for treatment of 1 ha has therefore to be based mainly on economic considerations.

Under Philippine corn growing conditions and considering representative corn yields, prices of corn grain and costs of comparable

insecticide treatments, a quantity of 70 Trichocards/ha/release (equivalent to 105 000 - 140 000 Trichogramma/ha/release) was adopted as the standard recommendation by the PGBPPP.

The recommendation of 70 Trichocards/ha/release was tested in 1991/92 in two major corn areas. Results of the studies are summarized in Table 2. In Isabela (Region 2), two applications of 70 Trichocards/ha resulted in a corn borer damage reduction of 42% and a yield loss reduction of 6% (Table 2). In South Cotabato (Region 12), corn borer damage was reduced by 40% and yield loss by 19% by the same treatment (Table 2). The average relative grain yield of fields with Trichogramma releases in South Cotabato was 123% in comparison to untreated control fields (100%).

Again it was apparent that the effect of Trichogramma releases on corn yield was higher under a higher corn borer infestation level, as in South Cotabato, than under a lower level, as in Isabela.

Table 2. Effect of releases of *T. evanescens* on Asian corn borer damage and corn yield (1991/92 Studies)

Location and year	Trichogramma releases[1]	Corn borer damage: No. of tunnels/ 100 pl.	Corn borer damage: Damage reduct. in %	Corn yield: Grain yield (t/ha)	Corn yield: Rel. yield (%)	Corn yield: Yield loss red.(%)
Marana/ San Juan	2 x 70 cards	103	42	6.67	107	
Isabela Region 2 1991/92	no release	179		6.25	100	6
Marbel South Cotabato Region 12 1991/92	2 x 70 cards	178	40	6.11	123	
	no release	298		4.97	100	19

1) Mean of 6 sample fields.

Corn borer damage reduction of approximately 40% in both sites of the 1991/92 study was distinctly higher than in studies of the previous year regardless of the quantity of released Trichogramma (Table 1). The greater effectivity of Trichogramma releases in 1991/92 can probably be attributed to the bigger size of the treated and untreated areas during that year compared to the sizes of study fields in 1990/91, where emigration of Trichogramma to neighboring fields could have "diluted" the released Trichogramma population.

Effectiveness of *T. evanescens* in the Philippines as compared to other countries

The approximately 40% damage reduction rate obtained in the studies is rather low compared to previous studies in the Philippines and to experiences in European countries. TRAN & HASSAN (1986) reported reductions of up to 68% in numbers of larvae/corn plant and up to 71% in numbers of borer holes/plant in experiments conducted in the Philippines from 1983 to 1984. In Germany and Switzerland, effectivities of up to 85% average reduction of European corn borer larvae were obtained by releases of *T. evanescens* in farmers' fields (BIGLER et al. 1989, HASSAN et al. 1990).

It must be noted, however, that the respective data from the Philippines, Germany and Switzerland were derived from comparisons of Trichogramma-treated fields with control fields with either no or negligible Trichogramma parasitism. While in 1984 no natural Trichogramma parasitism was found yet in Philippine corn fields (see above) all untreated control fields in the 1990/91 and 1991/92 studies hosted substantial natural Trichogramma populations as a consequence of the establishment of *T. evanescens* after previous releases. Therefore it was expected that the effect of inundative releases here would be lower than in the absence of natural parasitism.

Trichogramma versus insecticides

A comparison of the different corn borer control methods of Trichogramma releases and insecticide applications shows that the same level of control can be achieved with two releases of Trichogramma or the common farmers' practice of one to two insecticide applications (HOFER 1988, VALDEZ 1992). This approximate equivalence can be deduced from the results of 31 insecticide trials in corn conducted between 1976 and 1990 in the Philippines. In a compilation of these experiments by KUGEL (1994), he calculated an average of 17% yield

loss prevention through the use of insecticides. Considering that insecticides were applied two to five times per crop in these trials, i.e., more frequent than in farmers' practice, and, again, that 24 out of 31 trials were conducted before *T. evanescens* began to become established, the effect of Trichogramma releases may definitely be regarded equivalent to insecticide treatments.

Results of a survey on changes in insecticide use among corn farmers after the introduction of Trichogramma also reflected this finding as being the farmers' perception (VALDEZ 1992). The number of farmers in the survey area who used insecticides dropped from 73% to 20% of the 200 respondents after introduction of the Trichogramma method. Reasons given for continued use of the Trichogramma method were that it was effective (32%), cheap (18%) and easy to use (18% of farmer respondents) (VALDEZ 1992).

Cost of Trichogramma application

As shown in the survey of VALDEZ (1992) corn farmers were motivated to continue the use of Trichogramma not only because of its effectiveness in terms of corn borer control but also because it was cheap and easy to use compared to the use of insecticides. At present, Trichocards in the Philippines are exclusively produced by laboratories of the Department of Agriculture and distributed to farmers virtually free of charge. However, most production centers eventually intend to either sell the cards at a price that covers at least the production costs or to turn over the technology to profit-oriented private enterprises for commercialization.

Estimates based on actual Trichocard production in the Regional Crop Protection Center in Davao (Region 11) and on a sensitivity analysis show that production costs for Trichocards may vary between ₱ 0.71 and ₱ 1.82 per card (KUGEL 1994). Similarly, cost monitoring of the Agricultural Pilot Center in Iguig (Region 2) shows that on a production level of approximately 300 000 cards in 1992, cards were produced at a total cost of ₱0.85 per card (SANA 1992, pers. communication).

A summary of the economic aspects of corn borer control using Trichogramma versus insecticides is given in Table 3. Assuming a price of ₱1.00 per card, representing Trichogramma production costs, or even of ₱2.00 per card, representing a hypothetical future sales price, the recommended number of Trichocards would still cost the farmer much less than the commonly used kinds and quantities of insecticides.

Moreover, no further investment costs are incurred by the farmers for the Trichogramma method, while they have to spend approximately ₱1 500.00 for a knapsack sprayer to apply insecticides.

A further valuable advantage of the Trichogramma method lies in the extremely low labor requirement for field application, i.e., 1 to 2 person hours/ha and crop for Trichocards as compared to 2 to 3 person days/ha and crop for insecticides (Table 3).

Table 3. Comparison of economic aspects of Asian corn borer control using *T. evanescens* versus insecticides

	Trichogramma	Insecticide
Method	2 applications of 70 cards/ha	1 - 2 applications of liquid insecticide
Cost of Trichocards /ha or	₱ 0.00 (Present practice, ₱ 0.00/pc.)	₱ 405.00[1)]
Cost of insecticides /ha	₱ 140.00 (Sale of cards at production cost of ₱ 1.00/pc.) ₱ 280.00 (Sale of cards at hypothetical price of ₱ 2.00/pc.)	
Investment for farm supplement	------	₱ 1 500.00 (Knapsack sprayer)
Labor for application	1 - 2 person hours/ha and crop	2 - 3 person days/ha and crop[2)]

1) Source: VALDEZ (1992) 2) Source: HOFER (1988).

Benefits for non-Trichogramma users

Additionally, it must be noted that even those farmers who are neither using Trichocards nor insecticides are benefited considerably from Trichogramma through its permanent establishment. In a survey of 113 corn fields in Mindanao, conducted 1989 and 1990, KUGEL (1994) reported an average parasitization rate of 43% of all corn borer eggs without any Trichogramma releases during the survey seasons. He attributed an approximate corn borer damage reduction of 30% to the presence of permanently established Trichogramma populations.

Ecological significance of Trichogramma

Lastly, the ecological significance of the adoption of the Trichogramma method must not be forgotten. As pointed out by VALDEZ (1992), most Trichogramma users discontinue the use of insecticides. Thus the insecticide residues in corn, the contamination of the environment and the hazards to health of farmers previously applying insecticides are greatly reduced.

SUMMARY

Results of field studies on releases of *Trichogramma evanescens* to control the Asian corn borer in 1990/91 and 1991/92 as well as findings and conclusions relating to Trichogramma releases under Philippine conditions indicate the following:

1. Two releases of 75 000 - 200 000 *T. evanescens*/ha in corn fields with permanently established Trichogramma populations from previous releases yielded up to 44% corn borer damage reduction and prevented yield losses of up to 19%.

2. Two releases of Trichogramma provide similar effects on reduction of corn borer damage and corn yield loss as one to two insecticide applications per corn crop.

3. For an effective and economical control of the Asian corn borer two applications of 70 Trichocards/ha each are recommended.

4. Considering the typical oviposition pattern of the Asian corn borer, the first batch of Trichocards should be applied four weeks after planting, i.e., at the onset of corn borer oviposition. The second application of Trichocards should follow one week after the first one.

5. Compared to insecticide treatments, the Trichogramma method is considerably cheaper due to: (1) lower costs of Trichocards compared to insecticides, (2) no requirement for investments for farm supplements like knapsack sprayers and (3) extremely low labor requirements in its application.

6. Even without actual releases all corn farmers in the major corn areas of the Philippines benefit from permanently established populations of *T. evanescens* which remain after previous releases. Corn borer damage reduction due to permanently established

Trichogramma populations has been estimated to reach average rates of 30%.

7. The decision to additionally inundate corn fields with *T. evanescens* at the onset of corn borer oviposition should be based on the expected corn yield as well as on the severity of corn borer infestation.

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