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Effect of Releasing Trichogramma embryophagum (Hymenoptera:Trichogrammatidae) on Controlling Asiatic Corn Borer(Lepidoptera:Pyralidae)in Taiwan[1]

Bing-Huei Chen and Jih-Zu Yu[2]

Abstract : *Trichogramma embryophagum* Hartig, an exotic egg parasitoid, was evaluated in the corn fields at the experimental farm of Taiwan Agricultural Research Institute for its efficacy on parasitizing the eggs of the Asiatic corn borer, *Ostrinia furnacalis* Hubner in Taiwan. Results showed that *T. embryophagum* significantly increased the parasitism percentage of the *O. furnacalis* egg mass and the eggs within each mass up to 100% in the released plots comparing to that of the control in both spring and fall cropping seasons of 1993 and 1994. Also, *T. embryophagum* predominated over the indigenous *T. ostriniae and T. chilonis* in relative percentage recovered from the eggs of *O. furnacalis* collected in the released treatments. The plots with the release of *T. embryophagum* had significantly higher yield of fresh ear, less damage percentage, and higher weight and percentage of marketable ear than those of the control treatment in both cropping seasons of 1994. The percentage of marketable ear in released treatment was over 90% in both cropping seasons while that of the control was only 3.8% with 100% damaged fresh ear in the spring cropping season. Results from this study therefore revealed that the exotic egg parasitoid, *T. embryophagum* could be complementary to the indigenous *T. ostriniae and T. chilonis* in parasitizing the eggs of *O. furnacalis*. The biological control of the corn borer could be improved by the inoculative release of *T. embryophagum* in the fields.

Key words : Corn borer, *Trichogramma* egg parasitoids, Release, Biological control.

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1. Contribution No. 1875 from Taiwan Agricultural Research Institute.
2. Entomologist and Assistant, Department of Applied Zoology, TARI, Wufeng, Taichung, Taiwan, ROC.

INTRODUCTION

The Asiatic corn borer (ACB), *Ostrinia furnacalis* Hubner is the most serious insect pest of corn in Taiwan. It could damage leaves, tassels, silks, ears, and stalks of corn plants, and causes severe loss in yield. For its control, farmers used to applying insecticides and *Bacillus thuringiensis* when ACB larvae occurred at whorl and pollen heading stages. Because the consumers demand residue-free agricultural products, it would therefore be wise to adopt an alternative biological control method. Since mid-1980's, an indigenous egg parasitoid, *Trichogramma ostriniae,* has been released in the corn fields for controlling *O. furnacalis* in Taiwan [6]. Temperature has been reported affecting parasitization efficiency of several species of *Trichogramma*[5,13]. This wasp could provide good parasitism on eggs of corn borer in fall cropping season, but the parasitism is unsatisfactory in spring cropping season especially when the weather is wet and the ambient temperature drops below 20°C[3]. Generally, ACB in Taiwan occurs more seriously in spring than in fall cropping season that releasing *T. ostriniae* alone is unable to obtain high enough parasitism to suppress the corn borer population below economic injury level.

Totally twenty exotic and indigenous *Trichogramma* species reared in the beneficial insect laboratory of Taiwan Agricultural Research Institute had been tested for their suitability to eggs of *O. furnacalis* in order to improve their parasitism on egg masses in spring cropping season. Results revealed that *T. embryophagum* and *T. evanescens* showed the most promising potential for parasitizing the corn borer eggs. Chen[3] reported that *T. embryophagum* had higher parasitism under 22°C, with longer longevity at 18°C, and predominated over *T. ostriniae* in recovery percentage from host eggs in laboratory conditions. Whether *T. embryophagum* performing in field conditions as well as that in laboratory is needed to be further tested.

Introduction of single or multiple species, or exotic or indigenous natural enemies for controlling a target insect pest is always a controversial issue among biological control workers[7,10,11]. The opposite opinion of having additive effect or competitive exclusion draws intensive argument. Researchers reported that simultaneously releasing two or more species of natural enemies may not be necessary permitting the occurrence of competitive interaciton because they might have different preferred microhabitats[8] or due to abundant host population[11,14]. Therefore, the objective of this study is to determine whether the release of the exotic *T. embryophagum* in corn fields may have adverse or complementary effect along with the indigenous *Trichogramma* species on the control of *O. furnacalis* in Taiwan.

MATERIALS AND METHODS

The plants: Super sweet corn, Honey 236, was planted at spacing of 90×30 cm in plots of total 0.6 ha in the experimental farms of Taiwan Agricultural Research Institute (TARI) at Wufeng, Taichung in both spring and fall cropping seasons of 1993 and 1994. The corn was grown on March 12 and August 25, 1993 for the spring and fall cropping season of 1993 respectively, while that of 1994 was on March 3, and August 26, 1994. The corn plants

received conventional fertilizer application and tillage management except no chemical application throughout the growing season. When the corn plants reached whorl stage, 20 plants from each of the four replicated plots of 0.05ha with 10 m apart were sampled, and the egg masses on each plant were collected and put individually into glass vial to check the parasitism rate and the recovery percentage of species before releasing *Trichogramma* egg parasitoids.

The parasitoids: Culture of the exotic *T. embryophagum* maintaining in the beneficial laboratory of TARI was used in this experiment. They have been reared and propagated in the laboratory for generations by parasitizing the eggs of rice moth, *Corcyra cephalonica* Stainton reared in the insectary. The emerged adult moths were collected daily and placed into oviposition cylinders for laying eggs. The deposited eggs were collected daily and sprayed on glued paper card of 50×30 cm in size. The eggs on the cards were then irradiated at 15 cm under UV light of 190 luxes for one hour to prevent the embryo from development before exposing to *Trichogramma* wasps for mass rearing.

Field release and sampling method: There were two treatments of with or without releasing *T. embryophagum* in this experiment. In spring and fall cropping seasons of 1993, field releases were made on May 10, 17, and 24, and on October 5, 12, 19, and 26 respectively. In spring and fall cropping seasons of 1994, field releases were conducted on April 20, 27, May 6, and 11, and on September 29, and on October 6, 13, and 20, respectively. Twenty egg cards each containing about 100 nearly emerging *T. embryophagum* pupae were randomly stapled underneath the leaves of corn plants in the releasing plots. The other field of 0.2 ha consisting of four plots of 0.05 ha each and about 200 m apart from the released site was used as the control where only the indigenous *T. ostriniae* and *T. chilonis* were present. One week before the first releasing till the end of each respective cropping season, 20 plants were randomly sampled weekly from each plot and the egg masses of corn borer on each plant were thoroughly collected. Only two samplings were made on May 17 and 24 for the spring cropping season in 1993 due to continuously raining for 3 weeks that destroyed the corn plants in the plots. The collected egg masses was each put into a glass vial sealed with parafilm and kept in chamber at 25°C. The parasitized eggs then turned dark whereas those unparasitized began to hatch, and their respective number was recorded to determine the percentage of parasitism for egg masses and for individual egg. The parasitized egg mass in each vial was allowed to let the parasitoids emerge and die. Specimen in each vial were sexed, and those males were mounted and identified by using Olympus BHS microscope to count the frequency of each species. At harvest, 20 plants were randomly sampled and the ears on each plants were collected and weighted. Number of ear with or without damage was counted and weighted. Harvested ears will be categorized into unmarketable and marketable ones included those without or with only slight damage by ACB. The percentage of egg mass parasitized, the percentage of eggs parasitized per mass, the recovery percentage of each *Trichogramma* species from each sample, the weight of fresh ears, the percentage of ear damaged, and the weight and the percentage of marketable ears were tabled and compared between the released and the control plots by PROC ANOVA in Statistical Analysis System

and t-Test was used to separate means at different levels of significance.

RESULTS AND DISCUSSION

In spring cropping season of 1993, percentage of egg mass parasitized by the indigenous *T. ostriniae* and *T. chilonis* was 73.8% in the released fields, then reached 96.7% and up to 98.6% within two weeks after releasing the exotic *T. embryophagum* which contributed about 25% increment in parasitism and was significantly higher than that of the control at each of respective sampling date (Table 1). Only three samplings were made in this season due to continuously raining for two weeks that destroyed the corn plants in fields.

Table 1. Parasitism percentage of egg mass of *O. furnacalis* and progeny sex ratio in the treated and the control plots before and after releasing *T. embryophagum* in the spring cropping season of 1993

Date[z] M/D	% parasitism of egg mass (Mean±SE)[y]		% parasitism of eggs (Mean±SE)		Progeny sex ratio	
	Treated	Control	Treated	Control	Treated	Control
5/10	73.8±3.8	5.0± 5.0	55.8±4.9	5.5± 5.5	1.6	4
5/17	96.7±1.9**	10.0±10.0	92.8±2.5**	10.0±10.0	1.9	22
5/24	98.6±2.5*	70.0± 9.8	91.3±2.3*	67.3± 9.6	1.4	3.8

[z] Planting date on March 12, 1993.
[y] * : $p<0.05$; ** : $p<0.01$, t test.

Before the field release of *T. embryophagum* on October 5 in fall cropping season of 1993, the indigenous *Trichogramma* species contributed only 16.7% and 0% of parasitism rate on the egg masses of *O. furnacalis* in the released and in the control plot respectively. One week after releasing the exotic species into corn fields, the percentage of parasitism sharply increased to 93.3%, and was 100% at the end of season while that of the control at each of respective sampling date was significantly lower ranging from 0 to 22.2%(Table 2). Similar results were obtained in the percentage of *O. furnacalis* egg mass parasitized in both spring and fall cropping seasons in 1994(Tables 3 & 4). Before releasing *T. embryophagum*, none of egg masses sampled on April 20, and on September 29, 1994 was parasitized. One week after release, the parasitism rates were 76.9% and 83.6% in the released plots which were significantly higher than that in the control for the spring and the fall cropping season respectively. The parasitism rate in the released plots increased with the plants grew toward maturity and was up to 100% at the end of both seasons in 1994(Table 3 & 4). The results showed that *T. embryophagum* and *T. ostriniae* did not interfere with each other in parasitization efficiency, and were successful in sharing the hosts which is similar to the relationship between *T. brassicae* and *T. cacoeciae* exploiting the eggs of flour moth, *Ephestia kuehniella*, reported by Bouletreau *et al.*[1].

Table 2. Parasitism percentage of egg mass of *O. furnacalis* and progeny sex ratio in the treated and the control plots before and after releasing *T. embryophagum* in the fall cropping season of 1993

Date[z] M/D	% parasitism of egg mass (Mean±SE)[y]		% parasitism of eggs (Mean±SE)		Progeny sex ratio	
	Treated	Control	Treated	Control	Treated	Control
10/ 5	16.7±16.7	0	16.7±16.7	0	2.7	—
10/12	93.3±6.3**	22.2±14.5	87.8± 7.0**	9.2±6.6	1.4	—
10/19	87.5±4.2**	8.3± 8.3	75.4± 7.6**	2.3±2.3	1.7	—
10/26	76.9±2.5**	20.0±20.0	70.1±11.9**	4.2±4.2	1.8	—
10/ 2	100**	0	92.9±3.1**	0	1.5	—

[z] Planting date on August, 25, 1993.
[y] *: $p<0.05$; **: $p<0.01$, t test.

Table 3. Parasitism percentage of egg mass of *O. furnacalis* and progeny sex ratio in the treated and the control plots before and after releasing *T. embryophagum* in the spring cropping season of 1994

Date[z] M/D	% parasitism of egg mass (Mean±SE)[y]		% parasitism of eggs (Mean±SE)		Progeny sex ratio	
	Treated	Control	Treated	Control	Treated	Control
4/20	0	0	0	0	—	—
4/27	76.9±6.8**	0	70.3±6.6**	0	1.8	—
5/ 6	89.4±3.6**	8.6±4.8	84.0±3.8**	6.6±3.8	1.5	2.1
5/11	92.6±4.2**	27.5±6.6	89.6±2.9**	26.3±6.8	1.2	1.3
5/18	98.7±2.3**	24.6±8.5	95.3±3.1**	23.2±7.1	1.4	1.4
5/25	100**	69.2±7.5	98.2±2.1**	67.4±7.3	1.7	1.4
6/ 1	100**	0	88.6**	0	1.2	—

[z] Planting date on March 3, 1994.
[y] **: $p<0.01$, t test.

Table 4. Parasitism percentage of egg mass of *O. furnacalis* and progeny sex ratio in the treated and the control plots before and after releasing *T. embryophagum* in the fall cropping season of 1994

Date[z] M/D	% parasitism of egg mass (Mean±SE)[y]		% parasitism of eggs (Mean±SE)		Progeny sex ratio	
	Treated	Control	Treated	Control	Treated	Control
9/29	0	0	0	0	—	—
10/ 6	83.6±7.1**	0	79.8±8.5**	0	2.1	—
10/13	84.5±6.6**	35.0±11.9	83.2±1.0**	27.6±10.3	1.5	2.1
10/20	92.1±2.0**	33.5± 1.5	98.2±1.9**	30.9± 2.5	1.5	1.6
10/27	100**	36.5±12.9	100**	33.3±11.5	2.4	1.5
11/ 3	97.2±2.8[ns]	90.5± 5.0	95.2±2.8[ns]	84.1± 7.9	1.8	1.5
11/10	100[ns]	83.0± 7.1	93.5±6.5[ns]	80.9± 8.8	1.4	1.4

[z] Planting date on August 26, 1994.
[y] **: $p<0.01$, t test.

The percentage of eggs parasitized per egg mass was calculated. Results from both spring and fall cropping seasons in 1993 showed that the parasitism rate in the released plots increased respectively from 55.8% and 16.7% to 92.8%and 87.8% at one week after releasing the exotic egg parasitoids while that of the control especially in the fall cropping season was very low ranging from 0% to as high as 9.2% only (Table 1 & 2). Percentage of individual egg parasitized per egg mass in the released plots was significantly higher than that of the control at each sampling date in the spring and most of except the last two samplings in the fall cropping season in 1994(Table 3 & 4). The higher parasitism percentage of eggs within egg mass was, the fewer larvae of O. *furnacalis* could hatch and consequently, the lesser damage on corn plants. Results from this study showed that the exotic *T. embryophagum* has a complementary effect on the indigenous *T. ostriniae* and *T. chilonis,* and is capable of enhancing the parasitism rate to the *O. furnacalis* egg masses.

More female progenies emerged than those of male in the released plots with sex ratio ranging from 1.2 : 1 to 2.4 : 1 after field release. In the spring cropping season 1993, more females emerged from the control check than males with ratio up to 22:1. This sex ratio should be unfavorable to *T. ostriniae* populations in the fields because few males will result in producing all male progenies by the unmated female wasps since the parthenogenensis of *T. ostriniae* is arrhenotokous while *T. chilonis* has been found with thelytokous type of reproduction in Taiwan[4].

The percentages of different *Trichogramma* species recovered from each sample collected in both cropping seasons in 1993 and 1994 were listed in Tables 5−8. Before field release, only the indigenous *T. ostriniae* and *T. chilonis* recovered from the fields in spring and fall cropping season in 1993, but none of them was found in both seasons in 1994. After releasing, *T. embryophagum* predominated over the other egg parasitoids each sampling in both cropping seasons in 1993 and 1994. Results from egg masses of *O. furnacalis* collected on May 17, 1993 showed that *T. embryophagum* occupied 73.3% of the emerged wasps with 23.6% of *T. ostriniae,* and 3.1% of *T. chilonis.* In fall cropping season 1993, *T. embryophagum* constituted 77.0%, 77.4%, 77.4%, and 89.1% of recovery rate which was significantly higher than that of the two domestic species collected on October 12, 19, 26, and November 2, respectively. Similar results were obtained in spring and fall cropping seasons of 1994, *T. embryophagum* reached the highest 93.5% of recovery rate with 5.6% of *T. ostriniae,* and 0.9% of *T. chilonis* on October 6, 1994. Only *T. ostriniae* and *T. chilonis* recovered from the control in both cropping seasons and years. Results coincided with those from the laboratory and the greenhouse studies that *T. embryophagum* predominated over *T. ostriniae* in parasitizing host eggs when they were simultaneously released for exploiting the eggs of corn borer [3]. Also, species displacement did not happen in this study which proved that *T. embryophagum* has the ability to discriminate between parasitized and unparasitized ACB eggs. Similar result was reported by Klomp *et al.*[12] on *T. embryophagum* that could discriminate parasitized and unparasitized eggs of the flour moth.

Table 5. Relative percentage of *Trichogramma* species recovered from egg masses of *O. furnacalis* collected before and after releasing *T. embryophagum* in the spring cropping season of 1993

Species	Sampling date (month/day)							
	5/10		5/17		5/24		5/31	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control
T. ostriniae	96.7a[z]	100a	23.6b	100a	37.3b	77.8a	—	—
T. chilonis	3.3b	0b	3.1c	0b	2.4c	22.2b	—	—
T. embryophagum	0b	0b	73.3a	0b	60.3a	0c	—	—

[z] Means in each column followed by the same letter are not different significantly at 5% level according to Duncan's New Multiple Range Test.

Table 6. Relative percentage of *Trichogramma* species recovered from egg masses of *O. furnacalis* collected before and after releasing *T. embryophagum* in the fall cropping season of 1993

Species	Sampling date (month/day)									
	10/5		10/12		10/19		10/26		11/2	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
T. ostriniae	71.4a[z]	0	19.5b	0	17.0bc	0	20.5b	0	10.8bc	0
T. chilonis	28.6b	0	3.5c	0	5.6c	0	2.1c	100	0c	0
T. embryophagum	0c	0	77.0a	0	77.4a	0	77.4a	0	89.1a	0

[z] Means in each column followed by the same letter are not different significantly at 5% level according to Duncan's New Multiple Range Test.

Table 7. Relative percentage of *Trichogramma* species recovered from egg masses of *O. furnacalis* collected before and after releasing *T. embryophagum* in the spring cropping season of 1994

Species	Sampling date (month/day)													
	4/20		4/27		5/6		5/11		5/19		5/25		6/1	
	T[z]	CK	T	CK	T	CK	T	CK	T	CK	T	CK	T	CK
T. ostriniae	0	0	21.2b[y]	0	23.2b	55.6a	16.9bc	73.8a	14.0bc	70.6a	13.6bc	69.1a	20.5b	0
T. chilonis	0	0	5.3c	0	4.0c	44.4a	3.1c	26.2b	2.5c	29.4b	3.9c	30.9b	5.5c	0
T. embryophagum	0	0	73.5a	0	72.8a	0b	80.0a	0c	83.5a	0c	82.6a	0c	74.0a	0

[z] T : Treated ; CK : Control.
[y] Means in each column followed by the same letter are not different significantly at 5% level according to Duncan's New Multiple Range Test.

Table 8. Relative percentage of *Trichogramma* species recovered from egg masses of *O. furnacalis* collected before and after releasing *T. embryophagum* in the fall cropping season of 1994

Species	Sampling date (month/day)											
	9/29		10/6		10/13		10/20		10/27		115/3	
	T[z]	CK	T	CK	T	CK	T	CK	T	CK	T	CK
T. ostriniae	0	0	5.6bcy	0	7.7bc	70.3a	6.3bc	83.9a	7.8bc	76.4a	8.3bc	78.8a
T. chilonis	0	0	0.9c	0	1.8c	29.7b	2.3c	16.1b	0.8c	23.6b	3.6c	21.2b
T. embryophagum	0	0	93.5a	0	90.5a	0c	91.4a	0c	91.4a	0c	88.1a	0c

[z] T : Treated ; CK : Control.
[y] Means in each column followed by the same letter are not different significantly at 5% level according to Duncan's New Multiple Range Test.

Effect of releasing *T. embryophagum* on the yield of corn was significant between treatments in both spring and fall cropping seasons in 1994(Table 9). In spring 1994, the weight of fresh ears per 20 plants, the percentage of ears damaged, the weight and the percentage of the marketable ears was 5.8 kg, 41.1%, 5.3 kg, and 90.7% respectively for the release plots while that of the control was 1.5 kg, 100%, 1.0 kg, and 3.8%, respectively with significant difference between treatments. In fall 1994, the respective item recorded for the releasing plots was 6.7 kg, 17.8%, 6.3 kg, and 94.0% which was significantly better than that of the control of 3.8 kg, 68.9%, 1.4 kg, and 36.8%, respectively. The results showed that releasing *T. embryophagum* into corn fields reduced the damage of corn ears and increased its marketable ear yields.

Table 9. Difference in yield, damage, and marketable percentage of fresh ears between plots with or without releasing *T. embryophagum* in the spring and the fall cropping season of 1994

Treatment	Weight (kg) of fresh ears/20 plants		% fresh ears damaged		Weight (kg) of marketable ears/20 plants		% marketable ears	
	Spring[z]	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Release	5.8**	6.7*	41.1	17.8	5.3**	6.3**	90.7**	94.0*
Control	1.5	3.8	100*	68.7*	0.1	1.4	3.8	36.8

[z] *p<0.05 ; **p<0.01, t Test.

Trichogramma species have been widely used for the control of major insect pests [2,6,15]. Recently, the impact of exotic wasps on non-target hosts has been concerned by researchers [9]. Based on the data obtained from this study, the problem that concerned is unlikely to happen for *T. embryophagum.* Since the release of this exotic species in 1993, it has shown additive effect along with the local *Trichogramma* species against *O. furnacalis.* However, its field occurrence suggested that it has not yet established in Taiwan because it did not recover from each sample collected before release in both spring and fall cropping seasons in 1994. Nevertheless, survery on this exotic species should be continued and closely checked to make sure its establishment in Taiwan. Results from this study revealed that *T. embryophagum* can be supplementary to *T. ostriniae* in checking *O. furnacalis* at acceptable low level especially in spring cropping season when the corn borer is much abundant and the environmental conditions are unfavorable to the activities of the local parasitoid. The relationship between *T. embryophagum* and *T. ostriniae* truly illustrated what stated by Moon[14] as "following the introduction of species B, coexistence with species A may be a common event, even when A and B compete for several resources, and that the competitive exclusion may not adequately apply to the heterogeneous real world".

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釋放外來卵寄生蜂*Trichogramma embryophagum* Hartig防治亞洲玉米螟[1]

陳炳輝 余志儒[2]

摘要：在臺灣省農業試驗所之試驗農場進行田間釋放，評估外來卵寄生蜂*Trichogramma embryophagum* Hartig 對亞洲玉米螟*Ostrinia furnacalis* Hubner 卵之寄生效果。在1993年與1994年春秋兩季之試驗結果顯示，此種外來卵寄生蜂在釋放區可增加對玉米螟卵塊與卵粒之寄生率，最高可達100%而與對照無釋放區呈顯著之差異。定期自釋放區與對照區取樣玉米螟卵塊，比較各蜂種回收比率之結果顯示，在釋放區 *T. embryophagum* 均比另外兩種本地卵蜂 *T. ostriniae* 與 *T. chilonis* 爲優勢。釋放與否對玉米穗收量之影響，結果顯示 *T. embryophagum* 卵寄生蜂在1994年春秋兩季於釋放區可顯著增加玉米鮮穗重、減少穗受害率、增加可上市穗率與穗重，而與對照區呈顯著之差異。在釋放區之玉米穗可上市穗率，無論春秋兩季均可達90%以上。而對照區之玉米穗受害率高達100%而可上市穗率僅有3.8%。綜合本試驗結果顯示，*T. embryophagum* 卵寄生蜂與另外兩種本地種 *T. ostriniae* 與 *T. chilonis* 對玉米螟卵之寄生俱互補作用，定期釋放該寄生蜂將可加強玉米螟之生物防治。

關鍵詞：玉米螟、玉米螟赤眼卵寄生蜂、釋放、生物防治。

1. 臺灣省農業試驗所研究報告第 1875 號。本計畫承農委會玉米基金經費補助（82—玉米—3；83—玉米—2），吳德忠先生、劉琇引小姐協助試驗，謹致謝忱。
2. 本所應用動物系副研究員與助理。臺灣省 臺中縣 霧峰鄉。