THE INTEGRATION BETWEEN TRICHOGRAMMA EVANESCENS WEST. (HYMENOPTERA: TRICHOGRAMMATIDAE) AND SELECTED BIOINSECTICIDES FOR CONTROLLING THE POTATO TUBER MOTH PHTHORIMAEA OPERCULELLA (ZELL.) (LEPIDOPTERA: GELECHIIDAE) OF STORED POTATOES

Nasser Said Mandour, Awad Ahmed Sarhan*, Dina Hussien Atwa

Department of Plant Protection, Faculty of Agriculture
Suez Canal University, 41522 Ismailia, Egypt

Received: November 7, 2010
Accepted: September 7, 2011

Abstract: The efficacy of the egg-egg parasitoid Trichogramma evanescens (Hymenoptera: Trichogrammatidae) and certain bioinsecticides (e.g., Neemix, Virotecto, Agerin, Dipel 2x and Spinosad) for controlling the potato tuber moth (PTM), Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae) under storage conditions was studied. Single and combined treatments of T. evanescens and the bioinsecticides were tested. Neemix and spinosad were evaluated as spray treatments. Virotecto, Agerin and Dipel 2x were evaluated as dust and spray treatments. Data were recorded in terms of rate of infestation, reduction of infestation, number of P. operculella pupae, and number of mines per 20 tubers as well as percentage of edible parts. Data revealed that the percentage of infestation in the control treatment was as high as in the Neemix treatment being 96.67 and 90% after one and two months of storage, respectively. Obviously, Spinosad and Dipel 2x were the most effective bioinsecticides in reducing tuber infestation and number of P. operculella recovered pupae. Virotecto and Agerin reduced rate of infestation and number of recovered P. operculella pupae over that of the control, but their effect was significantly lower than that of Spinosad or Dipel 2x. Moreover, there were significant differences among treatments in the form of the number of P. operculella tunnels and percentages of edible parts after two months in storage. Data further indicated that the integration between the tested bioinsecticides and T. evanescens enhanced the control of P. operculella. Significant differences in percentages of infestation, edible parts, number of recovered pupae as well as number of mines in stored potatoes existed between individual treatments (without Trichogramma) and combined treatments.

Key words: Phthorimaea operculella, Trichogramma evanescens, bioinsecticides, infestation, integration, storage

INTRODUCTION

Potato (Solanum tuberosum L.) is the most important vegetable crop in Egypt with 107,953 cultivated hectares, and a total production of 2,760,164 tons in 2007 (Ministry of Agriculture of Egypt, 2007). Under field conditions, potato plants are under attack by a large number of insect pests such as aphids, leafhoppers, and Lepidopterous pests. The potato tuber moth (PTM), Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae) is the most destructive pest. In addition to potato, P. operculella also attacks other solanaceous plants such as tomato, tobacco, eggplant and pepper in tropical and subtropical countries, but potato is still the preferred host plant (Shelton and Wayman 1979; Mandour 1997). In potato fields, the female P. operculella lays its eggs on the underside of the potato leaves or on the exposed tubers mainly after irrigation where potatoes are cultivated under the flooding irrigation system (Mandour 1997). PTM larvae mine the foliage, stems, and tubers (Islam et al. 1990; Mandour 1997). The larvae of P. operculella also form blotches in leaves and fold leaves over for shelter during feeding and for pupation (Mandour 1997). The new mines are always present in the upper part of the potato canopy. The old blotches, harboring the older larvae of PTM, are likely to be found the lower parts of the potato canopy particularly near the soil surface. Larvae may also bore into potato stem and petioles (Mandour 1997). There is usually a 10% rate of tuber infestation by P. operculella, but when control measures are not used, the infestation rate may reach 100% (Shelton and Wayman 1979; Mandour 1997; Sileshi and Teriessa 2001). In potato stores, infestation of P. operculella also causes partial or complete rotting by the subsequent infestation with fungi and/or bacteria. When rotting is present, it means the infested tubers are unmarketable (Shelton and Wayman 1979; Sarhan 2004).

Until the last 2 decades, the control of P. operculella has relied upon the use of the traditional insecticides (Sarhan 2004; Keasar and Sadeh 2007). Recently, biological control
The integration between Trichogramma evanescens West. (Hymenoptera: Trichogrammatidae) and selected bioinsecticides against P. operculella

MATERIALS AND METHODS

Rearing of P. operculella and T. evanescens

Laboratory cultures of P. operculella and T. evanescens were taken from the stock colonies kept on potato tubers under the laboratory conditions of 25±2°C, 60±10% Relative humidity (RH) and 14 h photophase in the Biological Control Center, Suez Canal University, Egypt. The ovipositional cage for PTM moths consisted of a glass jar (30 cm in height x 20 cm in diameter) covered with a piece of muslin cloth. Eggs of P. operculella were laid on the cloth sheet. Larvae of P. operculella were reared on potato tubers using the method described by Mandour (1997). As for T. evanescens, eggs of P. operculella were exposed to adult wasps in a glass tube (3x10 cm) for parasitization. T. evanescens adults were fed on a honey solution smeared on the inner wall of the glass tube.

Tested bioinsecticides

Five bioinsecticides were evaluated in this study. These bioinsecticides were Agerin, Dipel 2x (both are Bacillus thuringiensis – based insecticides), Virotecto (PTM virus), Spinosad and Neemix. Agerin, Dipel and Virotecto were tested as dust and spray treatments; whereas Spinosad and Neemix were tested only as spray treatments. The rate of application was identical to that described by Mandour et al. (2009). Spinosad and Neemix were used at the field rate of 0.5 ml/liter. Virotecto and Dipel 2x were used at 150 g/ton tubers for the dust treatment and at 1 g/liter for the spray treatment. Agerin was tested at the recommended rate of 250 g/ton tuber for the dust treatment or 250 g/40–60 liter for the spray treatment.

Experiments

Evaluation of selected bioinsecticides against P. operculella

This experiment was performed in a laboratory (4 m in width x 4 m in length x 3.5 m in height) at abiotic conditions of 25±2°C, 60±10% RH and 14 h photophase. Potato tubers were purchased, and then sorted out. Spoiled and PTM-infested tubers were removed and discarded. Only non-infested tubers were used. Four kilograms of potato tubers were assigned to form one replicate (each kg contained 6–7 tubers). Each treatment of biocides was replicated 6 times with a total of 24 kg tubers per treatment. The tested treatments were Neemix, Virotecto solution (VS), Virotecto dust (VD), Agerin solution (AS), Agerin dust (AD), Dipel solution (DS), Dipel dust (DD) and Spinosad.

The methodology and experimental setup used in this experiment were similar to that described earlier by Mandour et al. (2009). An assigned weight of potato tubers for each replicate was placed on a clean piece of cloth. Tubers were moistened with tap water using a small handled sprayer. The moistened tubers were then dusted with the assigned bioinsecticide using a small handled duster. Treated tubers were left to dry out for 2–3 hours. After that, the treated tubers were placed in a wooden cage (60 cm in width x 70 cm in length x 70 cm in height). A fine layer of clean sand (3–5 cm) was placed under the tubers in each cage to serve as the pupation site for PTM larvae. Cages were closed tightly, labeled, and placed on a steel stand under the aforementioned conditions. As for spray treatments, fresh solutions of the tested bioinsecticides were prepared 30 minutes prior application. The experimental setup and protocol including replicates, size of replicates, storage methods and doses were the same as those used in the dust treatment (Mandour et al. 2009). The control treatment was performed using the same protocol and replicates but without bioinsecticide application.

An artificial infestation was made using the rate of 6 PTM pupae/kg tubers, which was sufficient to inflict a 100% infestation rate, thus, the potato tubers were totally unmarketable (emergence rate was 90%, Atwa 2009). PTM pupae were placed in a Petri dish (9 cm), which in turn was placed inside each cage. After that, the tubers were checked weekly to remove the spoiled tubers. When PTM larvae start to pupate, the sand layer (under each treatment) was sieved thoroughly twice a week to collect the developed PTM pupae. Moreover, 20 tubers from each treatment were randomly selected each month to calculate the percentage of infestations, and the edible parts. This experiment lasted 2 months. Data were recorded in terms of rates of infestation, edible parts, and number of PTM pupae as well as number of PTM tunnels/20 tubers in each treatment.

Integration between T. evanescens and bioinsecticides against P. operculella

The obtained data in experiment 1 indicated that while some bioinsecticides treatments (e.g. spinosad and...
Dipel 2x) showed full protection against PTM, others (i.e. Neemix, Viroctecto and Agerin) did not give satisfactory control of PTM. Therefore, in this experiment the integration of the egg parasitoid *T. evanescens* (TE) and the bioinsecticides Neemix, Viroctecto and Agerin was investigated in cages under the previously mentioned conditions.

The methodology used in this experiment was similar to that described in experiment 1. After being treated with the biocides, potato tubers were placed inside the wooden cage. The artificial infestation with PTM pupae was initiated at the same rate used in experiment 1. Once adult moths emerged and started to deposit their eggs, *T. evanescens* was released in each cage at the rate of 6 *T. evanescens* black eggs (*P. operculella* eggs harboring *Trichogramma* pupae) per one kg potato tubers. *Trichogramma* pupae (black eggs) were released to emerge in successive forms. This form of release was done to guarantee the continuous presence of younger parasitoid females throughout the whole ovipositional periods of PTM moths. Data were recorded as percentages of infestation and edible parts, total number of PTM pupae, and number of PTM tunnels in the tubers.

**Statistical analysis**

All obtained data were analyzed using SAS package 8.2 v (SAS Institute 2003). Proportional data were transformed by arcsine square root before analysis. Data of percentages of infestation, reduction in PTM infestation, percentages of edible parts as well as number of mines were compared using ANOVA analysis of variance. When F values were significant, means were separated using Fisher’s least significant differences (FLSD) at a 0.05 level of significance (SAS Institute 2003). The T-test was used to compare the results of single and combined treatments.

**RESULTS**

**Evaluation of selected bioinsecticides against *P. operculella***

As shown in table 1, Spinosad and DD treatments gave satisfactory control of *P. operculella*. After 2 months of storage, no infestation was observed in the spinosad treatment, but infestation was minimal at 3.33% in the DD treatment (Table 1). Significant differences existed between the tested treatments after a month (F = 11.04; P = 0.0001) and 2 months (F = 8.20; P = 0.0001) of storage. Moreover, the numbers of recovered *P. operculella* pupae differed significantly between the biocide treatments and the control after a month (F = 194.17; P = 0.0001) and 2 months (F = 39.97; P = 0.0001) of storage. The tested bioinsecticides had a negative impact on the number of *P. operculella* mines (F = 69.51; P = 0.0001, table 1). The greatest number of mines was recorded in the control at 154 mines/20 tubers whereas the lowest was observed in the DD dust treatment – at 4.67 mines/20 tubers.

Moreover, the percentages of edible parts decreased gradually as the storage period increased. Spinosad showed full protection with an edible part of 100% after 2 months of storage. Significant differences among tested bioinsecticides in percentages of edible parts recorded after a month (F = 11.78; P = 0.0001) and 2 months of storage (F = 15.53; P = 0.0001) (Fig. 1).

**Integration between *T. evanescens* and bioinsecticides against *P. operculella***

As shown in table 2, the integration between the tested bioinsecticides and *T. evanescens* resulted in a significant reduction in the infestation rates of stored potatoes (F = 102.20; P = 0.0001), with a subsequent reduction in the number of recovered PTM pupae (F = 220.92; P = 0.0001) and the number of PTM tunnels in the tubers.

**Table 1.** Mean (±SE) of percentage of infestations, number of *P. operculella* recovered pupae, and number of mines in stored potato tubers treated with different bioinsecticides in cages

<table>
<thead>
<tr>
<th>Treatments</th>
<th>% of infestation after</th>
<th>No. of recovered PTM pupae after</th>
<th>No. of PTM mines/20 tubers*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 month</td>
<td>2 months</td>
<td>1 month</td>
</tr>
<tr>
<td>Control</td>
<td>96.67±3.33 a</td>
<td>90.00±5.77 a</td>
<td>177.33±2.60 a</td>
</tr>
<tr>
<td>Neemix</td>
<td>90.00±5.77 a</td>
<td>85.00±7.64 a</td>
<td>132.67±5.70 b</td>
</tr>
<tr>
<td>VS</td>
<td>68.33±9.28 ab</td>
<td>71.67±11.67 ab</td>
<td>117.67±6.44 c</td>
</tr>
<tr>
<td>WD</td>
<td>66.67±8.81 ab</td>
<td>60.00±9.28 ab</td>
<td>67.67±5.55 d</td>
</tr>
<tr>
<td>AS</td>
<td>43.33±1.86 b</td>
<td>41.67±8.78 b</td>
<td>54.66±4.81 ed</td>
</tr>
<tr>
<td>AD</td>
<td>38.33±1.67 bc</td>
<td>36.67±3.33 bc</td>
<td>46.00±5.57 e</td>
</tr>
<tr>
<td>DS</td>
<td>3.33±1.67 c</td>
<td>5.00±1.89 cd</td>
<td>14.66±3.18 f</td>
</tr>
<tr>
<td>DD</td>
<td>1.67±0.67 c</td>
<td>3.33±0.67 cd</td>
<td>3.33±1.86 gf</td>
</tr>
<tr>
<td>Spinosad</td>
<td>0 c</td>
<td>0 d</td>
<td>0 g</td>
</tr>
<tr>
<td>P&amp;F values</td>
<td>F = 11.04; P = 0.0001</td>
<td>F = 8.20; P = 0.0001</td>
<td>F = 194.17; P = 0.0001</td>
</tr>
<tr>
<td>LSD</td>
<td>33.75</td>
<td>36.65</td>
<td>13.26</td>
</tr>
</tbody>
</table>

VS – Viroctecto spray; WD – Viroctecto dust; AS – Agerin spray; AD – Agerin dust; DS – Dipel solution; DD – Dipel dust; P – P and F values are statistical data of probability and F values; PTM – potato tuber moth; FLSD – Fisher’s Least Significant differences

Different letters (column wise) indicate significant differences (FLSD; p < 0.05)

*based on data after 2 months of storage
The integration between Trichogramma evanescens West. (Hymenoptera: Trichogrammatidae) and selected bioinsecticides on the percentage of edible parts of stored potatoes after one and two months of storage

VS – Virotecto spray; VD – Virotecto dust; AS – Agerin spray; AD – Agerin dust; DS – Dipel solution; DD – Dipel dust.
Same letters indicate no significant difference (FLSD; p > 0.05)

Fig. 1. Effect of treatment with bioinsecticides on the percentage of edible parts of stored potatoes after one and two months of storage

Table 2. Mean (±SE) of percentage of infestations, number of P. operculella recovered pupae, and number of mines in stored potato tubers in combined treatments of bioinsecticides and T. evanescens after 2 months of storage

<table>
<thead>
<tr>
<th>Treatments</th>
<th>% infestation</th>
<th>No of recovered PTM pupae</th>
<th>No. of PTM mines/20 tubers ’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>96.67±3.33 a</td>
<td>208.67±2.96 a</td>
<td>154.00±7.09 a</td>
</tr>
<tr>
<td>TE only</td>
<td>71.67±6.01 b</td>
<td>62.00±7.37 b</td>
<td>51.00±1.53 b</td>
</tr>
<tr>
<td>Neemix + TE</td>
<td>45.00±2.89 c</td>
<td>40.67±5.61 c</td>
<td>50.33±1.86 b</td>
</tr>
<tr>
<td>VS + TE</td>
<td>41.67±4.41 c</td>
<td>25.33±4.84 d</td>
<td>53.33±4.91 b</td>
</tr>
<tr>
<td>VD + TE</td>
<td>13.33±1.68 d</td>
<td>17.67±3.53 de</td>
<td>20.00±3.00 c</td>
</tr>
<tr>
<td>AS + TE</td>
<td>8.33±1.6 d</td>
<td>12.00±3.21 de</td>
<td>21.67±2.85 c</td>
</tr>
<tr>
<td>AD + TE</td>
<td>3.33±1.66 d</td>
<td>7.67±4.33 e</td>
<td>16.67±2.73 c</td>
</tr>
<tr>
<td>F &amp; P values</td>
<td>F = 102.20; P = 0.0001</td>
<td>F = 220.92; P = 0.0001</td>
<td>F = 151.44; P = 0.0001</td>
</tr>
<tr>
<td>LSD</td>
<td>10.47</td>
<td>14.48</td>
<td>11.74</td>
</tr>
</tbody>
</table>

VS – Virotecto spray; VD – Virotecto dust; AS – Agerin spray; AD – Agerin dust; TE – T. evanescens
Means followed with the same letters (column wise) are not significantly different (FLSD; p > 0.05)
*based on data after 2 months of storage

Fig. 2. Effect of combined treatments of bioinsecticides and T. evanescens on the percentage of edible parts of stored potatoes

VS – Virotecto spray; VD – Virotecto dust; AS – Agerin spray; AD – Agerin dust; TE – T. evanescens.
Same letters indicate no significant difference (FLSD; p > 0.05)
and numbers of mines in tubers ($F = 151.44$; $P = 0.0001$). Obviously, the greatest infestation rate was observed in the control treatment – at 96.67%, and the lowest rate was recorded in the AD + TE treatment – at 3.33%. Moreover, combined treatments caused a significant increase in the percentages of edible parts ($F = 17.92$; $P = 0.0001$). The highest percentages of edible parts were recorded for AS + TE and AD + TE treatments at 95 and 96.67%, respectively (Fig. 2).

The $T$-test was used to compare the difference between the results of single treatments of bioinsecticides (without TE) with those of combined treatments with $T. \text{evanescens}$ (with TE). Percentages of infestation showed significant differences between the single or combined treatment as far as control was concerned ($t = 3.64$; $P = 0.4706$), Neemix ($t = 4.49$; $P = 0.1935$), VS ($t = 2.50$; $P = 0.2188$), VD ($t = 5.94$; $P = 0.0690$), AS ($t = 1.58$; $P = 0.0127$), AD ($t = 1.56$; $P = 0.0107$). Significant differences were also observed in the number of recovered PTM as far as control was concerned ($t = 18.46$; $P = 0.2782$), Neemix ($t = 11.41$; $P = 0.5945$), VS ($t = 13.78$; $P = 0.6614$), VD ($t = 7.36$; $P = 0.4299$), AS ($t = 7.96$; $P = 0.4844$) and AD ($t = 6.05$; $P = 0.8184$; table 3). Numbers of PTM tunnels in tubers showed significant differences between single and combined treatments as far as control was concerned ($t = 14.19$; $P = 0.0886$), Neemix ($t = 8.55$; $P = 0.1354$), VS ($t = 4.36$; $P = 0.4817$), VD ($t = 5.38$; $P = 0.4602$), AS ($t = 3.19$; $P = 0.2209$) and AD ($t = 4.12$; $P = 0.5403$, table 3).

**Discussion**

Bt-based insecticides (Agerin and Dipel 2x) differed dramatically in their efficacy in controlling PTM. Agerin was not as effective as Dipel in either of the two methods of application (dust or spray). The differences between both biocides might be attributable to: 1) the commercial formulation of both of them, and 2) their recommended doses. In earlier studies, the use of Bt at the recommended dose gave full protection against $P. \text{operculella}$ infestation for up to 255 days of storage [Salama et al. (1995) or 3 months (Mandour et al. 2009)]. On the contrary, Salama and Salem (2000) found that Dipel 8 l did not afford acceptable protection against $P. \text{operculella}$. Treatment with Bt-based biocides also caused significant reduction in number of PTM recovered pupae. These findings were also in agreement with those of Mandour et al. (2009) when Agerin and Dipel 2x were tested against PTM in gunny sacks.

Treating potato tubers with Spinosad in this study, showed full protection against $P. \text{operculella}$ for up to 2 months. Neither PTM mines nor pupae were observed in the Spinosad treatment. These findings confirm those reported earlier by Gomaa and El-Nenay (2006) who reported 100% protection against PTM with a very long persistence throughout the storage period, and Spinosad was found to be more effective than the organophosphorous insecticide, Tilton (Temerek 2003).

Neemix was ineffective for controlling $P. \text{operculella}$. This conclusion is in agreement with that reported for Neemix (Mandour et al. 2009) or Achook 300 ppm Azadirachtin (Chandel and Chandla 2005). These authors found that neem compounds were not effective against $P. \text{operculella}$ during storage. In contrast, neem treatments afforded acceptable protection against $P. \text{operculella}$ in storage for up to 3 months (Hossain et al. 1994; Debnath et al. 1998) and neem oil was as effective as the insecticide, Sevin (Salama and Salem 2000).

In the current study, Virotecto was not effective in controlling $P. \text{operculella}$. Islam et al. (1991) came to the same conclusion and also found that granulosis virus (GV) did not protect potato tubers from infestation with $P. \text{operculella}$. On the contrary, GV was reported to be very effective in controlling $P. \text{operculella}$ either in storage or in

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Parameters</th>
<th>% Infestation</th>
<th>No. of PTM pupae</th>
<th>No. of PTM mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>71.67±6.01</td>
<td>62.00±7.37</td>
<td>51.00±1.53</td>
</tr>
<tr>
<td></td>
<td>with TE</td>
<td>96.67±3.33*</td>
<td>208.67±2.96*</td>
<td>154.00±7.09*</td>
</tr>
<tr>
<td></td>
<td>without TE</td>
<td>45.00±2.89</td>
<td>40.67±5.61</td>
<td>50.33±1.86</td>
</tr>
<tr>
<td>Neemix</td>
<td></td>
<td>86.67±8.82*</td>
<td>158.00±6.62*</td>
<td>111.33±6.89*</td>
</tr>
<tr>
<td></td>
<td>with TE</td>
<td>41.67±4.41</td>
<td>25.33±4.84</td>
<td>53.33±4.91</td>
</tr>
<tr>
<td></td>
<td>without TE</td>
<td>75.00±12.58*</td>
<td>141.33±6.89*</td>
<td>97.00±8.72*</td>
</tr>
<tr>
<td>VS</td>
<td></td>
<td>13.33±1.68</td>
<td>17.67±5.53*</td>
<td>20.00±3.00</td>
</tr>
<tr>
<td></td>
<td>with TE</td>
<td>66.67±8.82*</td>
<td>73.67±6.74</td>
<td>53.67±5.49*</td>
</tr>
<tr>
<td></td>
<td>without TE</td>
<td>43.33±21.86*</td>
<td>64.00±5.69*</td>
<td>49.00±8.08*</td>
</tr>
<tr>
<td>VD</td>
<td></td>
<td>8.33±1.6</td>
<td>12.00±3.21</td>
<td>21.67±2.85</td>
</tr>
<tr>
<td></td>
<td>with TE</td>
<td>66.67±8.82*</td>
<td>73.67±6.74</td>
<td>53.67±5.49*</td>
</tr>
<tr>
<td></td>
<td>without TE</td>
<td>43.33±21.86*</td>
<td>64.00±5.69*</td>
<td>49.00±8.08*</td>
</tr>
<tr>
<td>AS</td>
<td></td>
<td>3.33±1.66</td>
<td>7.67±4.33</td>
<td>16.67±2.73</td>
</tr>
<tr>
<td></td>
<td>with TE</td>
<td>38.33±21.67*</td>
<td>48.67±5.21*</td>
<td>39.33±4.48*</td>
</tr>
<tr>
<td></td>
<td>without TE</td>
<td>38.33±21.67*</td>
<td>48.67±5.21*</td>
<td>39.33±4.48*</td>
</tr>
</tbody>
</table>

Table 3. Comparison between individual and combined treatments of different bioinsecticides and $T. \text{evanescens}$ against $P. \text{operculella}$ in cages

*indicated significant differences between the two compared treatments ($T$-test, $p < 0.05$)
the field even as dust, spray or as soil treatments (Chandel and Chandla 2005). Gomaa and El-Nenaey (2006) also found that the application of Virotecto or GV infected larvae more effectively controlled PTM infestation than Bt-based insecticides.

Individual treatment of the *T. evanescens* caused significant reduction of infestation and decreased number of mines per tubers 3 times as compared to the control. These findings agree with those reported by Saour (2004) who found that *Trichogramma* spp. caused significant reduction in *P. operculella* emerged adults and generation survival when wasps were released over potato plants or potato hills. Rubio et al. (2004) also found that a frequent release of *T. lopezandinensis* at 3 day-intervals in a wooden cage achieved good control of PTM, indicating that the continuous presence of young females of *Trichogramma* was critical for achieving a better level of parasitization.

Mikhael (1999) found that the use of *T. minutum* caused the lowest number of mines/25 potato tubers. The release of *T. evanescens* for three times in potato fields caused a drop in the rate of tuber infestation to 6.84% compared to 18.45 and 15.23% in fields sprayed once or twice with Selectron, respectively (Agamy 2003).

The integration of *T. evanescens* and biocides enhanced the control of PTM in storage over that of single treatment (*Trichogramma* alone or biocide alone). The number of recovered PTM pupae and number of mines per tubers were 4 and 2 times lower than those of the control, respectively. These results may indicate several facts. First, the tested bioinsecticides (Neemix, Agerin and Virotecto) are not toxic to *T. evanescens*. Egg parasitoids have been found highly compatible with Bt, as the eggs of the host insect are not the target stage for the microbe. The release of *Trichogramma* in a Bt-based IPM program in tomato, improved profitability of this program when compared with the use of conventional insecticides (Trumble and Alvarado-Rodriguez 1993). Second, dust treatments of Agerin and Virotecto did not retard the searching parasitoids. Finally, there is an opportunity for further, large-scale integration of the biocontrol agents under field or storage conditions. Our findings are in agreement with *Phthorimaea operculella* in Himachal Pradesh. Indian J. Agric. Sci. 75 (4): 837–839.


ACKNOWLEDGEMENTS

The authors would like to thank all the technicians and workers of the Center for Biological Control, Suez Canal University for their help during the course of this study.

REFERENCES


