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# EFFECTS OF PEST MANAGEMENT PRACTICES ON HONEY BEE (*APIS MELLIFERA* L.) POLLINATORS AND YIELD OF BITTER GOURD

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## ABSTRACT

This study evaluated the effects of an integrated pest management (IPM) strategy and the application of chemical pesticides on honey bee pollinators and yield of bitter gourd. The IPM strategy included yellow sticky traps with methyl eugenol lures and weekly spray applications of a biopesticide, *Bacillus thuringiensis* (Xentari® 48.1% WDG). For the chemical pest management treatment, malathion 50% EC was sprayed at weekly intervals. This IPM strategy did not adversely affect the foraging activity of honey bees. However, malathion caused significant mortality of honey bees one day after application. Pollination by honey bees increased the number of bitter gourd fruit and also increased the yield to a maximum of 226%.

**Key words:** Integrated pest management (IPM), malathion, pesticides, honey bee, bitter gourd

## ABSTRAK

Kajian ini dilakukan bertujuan untuk menilai kesan kaedah pengurusan perosak bersepadu (IPM) dan penggunaan racun kimia pada lebah madu pendebunga dan hasil tanaman peria. Kaedah IPM yang digunakan termasuklah perangkap lekat kuning dengan feromon *metil eugenol* dan aplikasi semburan mingguan racun serangga biologi, *Bacillus thuringiensis* (Xentari® WDG 48.1%). Bagi pengawalan secara kimia, malathion 50% EC telah disembur pada setiap minggu. Didapati kaedah IPM ini tidak menjejaskan aktiviti ternakan lebah madu. Bagaimanapun, didapati penggunaan malathion telah menyebabkan kematian ketara kepada lebah madu bermula sehari selepas penyemburan. Namun begitu, pendebungaan oleh lebah madu meningkatkan pengeluaran buah dan hasil maksima buah peria sehingga 226%.

**Kata kunci:** pengurusan perosak bersepadu (IPM), malathion, racun perosak, lebah madu, peria.

## INTRODUCTION

Honey bees (*Apis mellifera* L.) are one of the most important pollinators of agricultural and horticultural crops. Honey bees have characteristics that make them valuable for crop pollination. Their body size and proboscis length suit them to forage various types of crops (Abrol, 2011). Although agronomic inputs such as manures, fertilizers, pesticides and irrigation are vital in crop production, pollination is essential to achieve desired quality and yield for many crops. Cucurbitaceous vegetables require insect pollinators such as honey bees to transfer pollen from male to female flowers. Research has shown that pollination by honey bees increases fruit size and seed number of cucurbit crops such as pumpkin (Walters and Taylor, 2006) and increased yield and quality of muskmelon (Gaye et al., 1991). Among the cucurbits, bitter gourd (*Momordica charantia* L.) is widely cultivated for its nutritional and medicinal content. Bitter gourd is consumed in South, Southeast and East Asia, and has been used for centuries in the traditional medicine practices of India, China, Africa and Latin America (Behera et al., 2010) to reduce blood sugar levels (Shetty et al., 2005). However, the use of honey bees as pollinators for bitter gourd has received scant research attention.

Insect pests are a serious problem in bitter gourd production. Common armyworm (*Spodoptera litura* Fabricius), pumpkin caterpillar (*Diaphania indica* Saunders), spotted beetles (*Epilachna* spp.), pumpkin beetles (*Aulacophora* spp.) and melon fly (*Bactrocera cucurbitae* Coquillett) feed on the leaves, flowers and/or fruits of bitter gourd, and cause serious losses (Gopalakrishnan, 2007). Various pest management practices are adopted to suppress pest populations below economic injury level. Integrated pest management (IPM) strategies and chemical pesticides are used to control pests on bitter gourd (Alam et al., 2008). However, pest management practices may be harmful to beneficial insects, including honey bees.

Significant mortality and reduced flight activity of adult bees were observed after the application of malathion in a Mediterranean fruit fly eradication program (Gary and Mussen, 1984). Malathion foliar residue is highly toxic to honey bees for as much as 48 hours after application (Newhart, 2006). In addition, high toxicity of pyrethroid pesticides to honey bees has been recorded in several studies (vanDame et al., 1995; Decourtye et al., 2004). For instance, imidacloprid, a systemic pesticide, was found to be toxic to two subspecies of *A. mellifera* (Suchail et al., 2000). Although Success 0.02 CB™ (GF-120), a formulation based on spinosad (a derivative of the naturally occurring actinomycete *Saccharopolyspora spinosa*), combined with ammonium acetate (an efficacious fruit fly attractant) contains a honey bee repellant, it was toxic to honey bees at varying levels, depending upon exposure and drying time in laboratory bioassays (Edwards et al., 2003). Subsequent field studies have shown that bees did not feed on GF-120 and also that honey bees were repelled by the fruit fly attractant components of the bait (Mangan and Moreno, 2009). Our study evaluated the effect of pest management practices on honey bee pollinators and yield of bitter gourd.

## MATERIALS AND METHODS

### Plant materials

Bitter gourd variety 'Gao Yue' $F_1$ hybrid (Known-You Seed Company, Taiwan) was used in the experiment because of its high flowering capacity. Bitter gourd seeds were sown in a greenhouse in mid-February 2012. In early March, seedlings were transplanted into the experimental field of AVRDC - The World Vegetable Center, Taiwan. The crop was grown following suggested cultural practices (Palada and Chang, 2003).

### Experimental design

The experiment followed a randomized complete block design (RCBD). Bitter gourd plants were grown with the support of trellis structures. There were 16 plots and each plot was 5 m x 5 m. The plots were covered with nylon net for the duration of flowering and fruiting in April. There were four treatments (untreated control without honey bees, untreated control with honey bees, honey bees + IPM strategy and honey bees + malathion treatment), each with four replications. For the IPM treatment, yellow sticky traps with methyl eugenol lures were installed to trap *B. cucurbitae*. *Bacillus thuringiensis* (Xentari® 48.1% WDG, Valent Biosciences Corporation, USA) was sprayed at the recommended dose in weekly intervals to manage *D. indica* and *S. litura*. For the chemical pest management treatment, malathion (50% EC, Cheminova A/S, Denmark) was sprayed at the recommended dose in weekly intervals.

### Honey bees

Twelve beehives with honey bees were obtained from a bee farm located in Xinhua district, Tainan, Taiwan in April, 2012. Each beehive contained three frames with about 7200 adult bees, taken from a standard six-frame colony. One beehive was placed in each net house enclosing the experimental plots, except the control treatment plots, and the honey bees were allowed to forage freely inside the net houses. Because the experimental plots are smaller and hence the flowers may not provide sufficient feed, a sugar solution was provided inside the net houses as a supplementary food. Sugar is an effective bee feed, because it stimulates bees to forage and breed.

**Honey bee foraging activity**

One day after the application of pesticides or biopesticides, activity of honey bees at the hive entrance was monitored in the morning between 08:00-11:30. Incoming and outgoing bees at the hive entrance were counted for five minutes with a timer clock (KGM-813W, Kolin).

**Mortality of honey bees**

The number of dead honey bees within an area of 1 m radius from the hive was counted in each plot one day after the application of chemical pesticides or biopesticides.

**Yield of bitter gourd**

Mature bitter gourd fruits were harvested every five days. The number of marketable and damaged fruit was counted at every harvest. In addition, the weight of marketable and damaged fruit was recorded.

**Statistical analysis**

Analysis of variance procedures was performed using general linear model procedures of SAS (Cary, N.C.).

## RESULTS AND DISCUSSION

**Honey bee foraging activity**

Neither the IPM strategy nor the chemical pest management practice affected honey bee activity. There were no significant differences in the mean number of incoming bees, outgoing bees and the total number of bees present at the hive entrance among the treatments (Table 1). The results indicate that malathion did not repel the foraging activity of the bees. If a pesticide is repellent, it might reduce the potential for bee poisoning (Riedl et al., 2006). Because bee activity after the application of malathion was not reduced in the current study, it might not reduce the potential for bee poisoning in malathion-treated plots.

**Table 1.** Honey bee activity at the hive entrance after one day of chemical and biopesticide applications

| Treatment | Mean number of bees‡ | | |
|---|---|---|---|
| | Incoming | Outgoing | Total bees at the hive entrance |
| Untreated control without honey bees‡‡ | – | – | – |
| Untreated control with honey bees | 26.63 | 13.50 | 61.63 |
| IPM | 20.38 | 9.56 | 45.88 |
| Malathion | 10.81 | 8.19 | 28.50 |
| F value | 3.24 | 0.95 | 1.56 |
| P value | 0.09 | 0.51 | 0.30 |

‡ The statistical analysis was performed after square-root transformation
‡‡ This treatment was omitted from statistical analysis, since it did not have any bee hives

**Mortality of honey bees**

Although the pest management practices did not reduce the foraging activity of the honey bees at the hive entrance, significantly high mortality was observed in plots sprayed with malathion (Table 2). However, the IPM strategy did not cause any significant mortality of honey bees, similar to the untreated control plots. Foragers (older bees) are more susceptible to pesticide exposure due to foraging activity than younger bees that stay in the hive (Rortais et al., 2005). When malathion is applied during the night or early in the morning when bees are not foraging in the field, mortality can be significantly reduced (Sanford, 2003). Because the malathion was applied in the late afternoon in our study, the foragers, which are usually three- to four-week-old worker bees, might have been exposed to the pesticide, thus causing the higher mortality. In addition, heavy losses of bees due to malathion application are possible under high temperature conditions (Sanford, 2003). During the study period, especially on the days of pesticide application, the temperature ranged between 32.9 – 36.3ºC in open field conditions and it was 2-3ºC higher inside the net houses. Hence, the temperature also could have contributed to the increased mortality of bees due to malathion application.

**Table 2.** Mortality of honey bees after one day of chemical and biopesticide applications

| Treatment | Mean number of dead bees‡ |
|---|---|
| Untreated control without honey bees‡‡ | – |
| Untreated control with honey bees | 3.17 b |
| IPM | 2.50 b |
| Malathion | 20.50 a |
| F value | 12.88 |
| P value | 0.0037 |
| LSD | 1.0032 |

Means followed by the same letter(s) are not significantly different by LSD at $P \leq 0.05$

‡ The statistical analysis was performed after square-root transformation

‡‡ This treatment was omitted from statistical analysis, since it did not have any bee hives

The yellow sticky traps baited with methyl eugenol did not attract the honey bees, and the mean trapping was less than a bee per trap. Some earlier studies have also confirmed that honey bees were caught mainly in white traps, followed by blue traps (Clare et al., 2000), but not with yellow sticky traps baited with pheromones of *Cydia pomonella* or *Epiphyas postvittana*. In our study the use of yellow sticky traps targeting fruit flies in cucurbits did not pose any serious threat to the honey bees.

**Yield of bitter gourd**

Introduction of honey bees in net houses significantly increased the total as well as the marketable number of bitter gourds (Table 3). Similarly, introduction of honey bees in the net houses significantly increased the total and the marketable yield of bitter gourd. The percentage increase in yield of bitter gourd fruit due to honey bee pollination varied from 186 to 226% in different treatments, when compared to plots without honey bee pollinators. In addition, the pest management practices reduced the number of damaged fruit. Thus, the marketable yield of bitter gourd increased significantly.

**Table 3.** Number and yield of bitter gourd fruit due to honey bee pollination after applying pest management practices

| Treatment | Number of fruits ('000) per ha | | | Yield (t/ha) | | |
|---|---|---|---|---|---|---|
| | Total | Unmarketable | Marketable | Total | Unmarketable | Marketable |
| Untreated control without honey bees | 12.00[b] | 5.30 | 6.70[b] | 4.65[b] | 1.72 | 2.93[b] |
| Untreated control with honey bees | 40.00[a] | 16.40 | 23.60[a] | 13.28[a] | 5.31 | 7.97[a] |
| IPM | 39.10[a] | 8.10 | 31.00[a] | 15.17[a] | 3.08 | 12.09[a] |
| Malathion | 40.30[a] | 12.00 | 28.30[a] | 14.12[a] | 4.13 | 9.99[a] |
| F value | 4.80 | 3.15 | 5.53 | 4.52 | 3.29 | 4.13 |
| value | 0.018 | 0.06 | 0.012 | 0.0218 | 0.0534 | 0.0284 |
| LSD | 15.15 | 7.20 | 11.15 | 5.51 | 2.24 | 4.692 |

Means within a column followed by same letter(s) are not significantly different by LSD at $P \leq 0.05$.

It is not uncommon that yield of various cucurbits increases with the introduction of honey bees. For instance, the individual fruit weights of *Cucurbita pepo*, *C. moschata* and *C. maxima* increased by 26%, 70% and 78%, respectively, when honey bee colonies were included by Walters and Taylor (2006). Bitter gourd and cucumber in net houses are pollinated by honey bees in Taiwan (Sung, 2010). Increasing crop yield and quality through insect pollination has direct economic value. It has been estimated that 80% labor cost savings per hectare can be obtained in watermelon and about 90% in cucumbers and bitter gourd production in Taiwan using bees as pollinators, instead of using labor for artificial pollination (Sung, 2010). Hence, honey bees play a vital role in enhancing the quality of bitter gourd fruit and productivity of bitter gourd plants.

## CONCLUSION

In this study, honey bee pollination increased the number of bitter gourd fruits, and the yield of bitter gourd increased to a maximum of 226%. However, the IPM strategy and a chemical pesticide treatment did not adversely affect honey bee (foraging) activity, although the pesticide application caused high mortality in honey bees one day after spraying. The yield was almost doubled due to the presence of honey bee pollinators in bitter gourd. Although this yield increase may not seem remarkable compared with those reported for other crops, it could be due to the smaller size of the experimental plots (25 $m^2$) in this study. Even a few honey bees can pollinate plants in such a small space, despite the application of broad-spectrum chemical pesticides such as malathion. The yield increase was the IPM treatment. Fruit did set in the control plots, even though no honey bees were introduced; this could be due to the presence of other insects or pollination by wind. Moths of *S. litura* and *D. indica* could have aided pollination in the control plots, as they were present in the net houses and were not affected by any pest management practices. It is possible to conclude that the presence of honey bee pollinators increases the yield in bitter gourd. In addition, the IPM strategy to manage insect pests on bitter gourd did not adversely affect the honey bee pollinators.

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