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ORIGINAL ARTICLE

Developing Pheromone Traps and Lures for *Maruca vitrata* in Taiwan

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Abstract The larvae of the legume pod borer, *Maruca vitrata* (Lepidoptera: Pyralidae), cause severe damage on economically important legume crops in the tropics. The female moth produces volatile components to attract males for mating. The so-called sex pheromones are species-specific multi-component blends and are used as lures in crop protection for pest monitoring. Their chemical identification and ratios is critical to design efficient lures. The following sex pheromone components for *M. vitrata* have been described: (*E, E*)-10,12-hexadecadienal (major compound), (*E, E*)-10,12-hexadecadienol and (*E*)-10-hexadecenal (minor components). The ratio of 100:5:5 of these components was the most attractive in trapping experiments in Benin, Africa. According to this ratio, a synthetic pheromone lure was developed for commercial use. But the commercially available blend was not attractive in field trapping experiments in other regions of sub-Saharan Africa and Southeast Asia. These findings lead to the conclusion that there is a possible polymorphism in the blend composition of the *M. vitrata* sex pheromone among populations from different geographical regions. In Taiwan, *M. vitrata* moths were never caught efficiently by the commercially available pheromone lures and traps. This paper reports trap and lure optimization experiments for effective trapping of Taiwanese *M. vitrata* moths in different leguminous crops.

Keywords *Maruca vitrata* · Sex pheromone · Lure · Polymorphism

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Entwicklung von Fallen und Lockstoffen *für Maruca vitrata* in Taiwan

Zusammenfassung Die Raupenstadien des Leguminosenbohrers *Maruca vitrata* (Lepidoptera: Pyralidae) verursachen in den Tropen schwere Fraßschäden an wirtschaftlich bedeutenden Gemüseleguminosen. Das Mottenweibchen produziert flüchtige Verbindungen und gibt diese ab um Männchen zur Paarung anzulocken. Diese sogenannten Sexpheromone sind artspezifisch und bestehen aus mehreren Komponenten. Im Pflanzenschutz werden synthetische Sexpheromone als Lockstoffe in Fallen eingesetzt, um den Schädlingsbefall zu kontrollieren. Ihre chemische Identifizierung und das Verhältnis der einzelnen Komponenten zueinander sind entscheidend, um effiziente Lockstoffe zu kreieren. Die folgenden Sexpheromonkomponenten sind für *M. vitrata* beschrieben: (*E, E*)-10,12-Hexadecadienal (Hauptkomponente), (*E, E*)-10,12-Hexadecadienol und (*E*)-10-Hexadecenal (Nebenkomponenten). In Feldversuchen in Benin, Afrika konnte mit einem Verhältnis dieser Komponenten von 100:5:5 die höchste Fangrate

erzielt werden. Basierend auf diesen Ergebnissen ist ein kommerzieller Lockstoff erhältlich. Dieser ist aber in anderen Regionen Subsahara-Afrikas und in Südostasien nicht effizient für den Fang von *M. vitrata*-Faltern gewesen. Diese Tatsache weist auf die Existenz eines Polymorphismus innerhalb der Sexpheromon-Zusammensetzung von geographisch verschiedenen Populationen dieser Art hin. In Taiwan war der Einsatz kommerziell erhältlicher Lockstoffe für *M. vitrata* nie erfolgreich gewesen. Dieser Beitrag berichtet über Feldversuche in Taiwan, die sich mit der Optimierung von Lockstoffen und Fallen beschäftigen um das Monitoring von *M. vitrata* Faltern zu verbessern.

Schlüsselwörter *Maruca vitrata* · Sexpheromon · Lockstoff · Polymorphismus

Introduction

Synthetic sex pheromones are a valuable tool in crop protection for pest monitoring, mass trapping, and/or mating disruption. Monitoring of insect pests and the use of control measures only when needed can help to reduce the overuse of pesticides in agriculture and horticulture applications. Moth sex pheromones are species-specific multi-component blends of compounds that are released by females to attract males for mating. Sex pheromones and their receptor proteins have been identified for several important Lepidopteran pests, e.g. *Helicoverpa armigera* (Zhang et al. 2012). In some species, such as in *Ostrinia nubilalis*, (Dopman et al. 2004) and *Spodoptera frugiperda* (Groot et al. 2008), the sex pheromone blends vary between populations. Thus, the chemical identification of sex pheromone components and their ratios is critical to design efficient lures.

The larvae of the legume pod borer, *Maruca vitrata* (Lepidoptera: Pyralidae), cause severe damage on economically important food legume crops in South- and Southeast Asia as well as sub-Saharan Africa. Several sex pheromone components of *M. vitrata* have been already identified (Adati and Tatsuki 1999; Downham et al. 2003). The major compound is (*E, E*)-10,12-hexadecadienal (*EE*10,12-16:Ald) (Adati and Tatsuki 1999) and as minor components (*E, E*)-10,12-hexadecadienol (*EE*10,12-16:OH) and (*E*)-10-hexadecenal (*E*10-16:Ald) were described (Downham et al. 2003). Although the sex pheromone blend composition could not be determined with analytical techniques, Downham et al. (2003) designed synthetic lures of *EE*10,12-16:Ald, *EE*10,12-16:OH and *E*10-16:Ald and found that the ratio of 100:5:5 ("Benin blend") was the most attractive in trapping experiments in Benin, Africa. According to this ratio, Russell IPM (Deeside, UK) developed a synthetic pheromone lure for commercial use. However, Benin blend was not attractive in field trapping experiments in other regions of sub-Saharan Africa and Southeast Asia (Downham 2005, personal communication, as cited in Hassan 2007, p. 127). These findings lead to the conclusion of a possible polymorphism presence in the blend composition of the *M. vitrata* sex pheromone among populations of different geographical regions.

The aim of the present study was to optimize lures and traps to monitor the *M. vitrata* population in fields of Southwestern Taiwan, because Taiwanese moths were never caught efficiently by the commercially available pheromone lures and traps (Srinivasan, 2012, personal communication). Two synthetic lures from already identified pheromone components based on the ratios that attracted *M. vitrata* male moths in trapping experiments in Benin (Downham et al. 2003, 2004) and Burkina Faso (Hassan 2007) were tested in the current study in different leguminous crops. Furthermore, we compared two different trap designs (delta trap and plastic funnel trap) for achieving optimum catch at two different heights in a yard long bean field.

Materials and Methods

The synthetic lures were obtained from the Bio-control Research Laboratories, Bangalore, India (BCRL). Lure 1 was 1 mg *EE*10,12-16:Ald (100) and lure 2 was 1 mg *EE*10,12-16:Ald, *EE*10,12-16:OH and *E*10-16:Ald in a ratio of 100:5:5 ("Benin-blend"). Polyethylene vials were used as pheromone dispensers. Three experiments were conducted using these lures.

Experiment 1 Sticky delta traps (Fig. 1a) and plastic funnel traps (Fig. 1b) with two windows (2×2 cm) on two opposite sides were tested in two heights (120 and 180 cm above ground) in the field. Lures (1 or 2) were placed in the center of each trap using a small wire paper-clip; they were replaced after 2 weeks and removed after another 3 weeks.

Fig. 1 Delta trap (**a**) and plastic funnel trap (**b**) in a yard long bean field

Table 1 Total catches of *Maruca vitrata*, *Spodoptera litura* and other non-target Lepidopterans per trap in yard long bean fields using delta traps and two lures at two different trap heights

Lure	Height (cm)	*M. vitrata*			*S. litura*	Non-target
		Male	Female	Sex unknown		
*EE*10,12-16:Ald	120	0 a	0.3±0.3 a	0 a	4.3±2.3 ab	2.0±1.5 a
	180	0 a	0 a	0.3±0.3 a	8.3±3.4 b	1.3±0.9 a
Ratio 100:5:5	120	0 a	0.3±0.3 a	0 a	0.3±0.3 a	1.7±0.3 a
	180	0.3±0.3 a	0.3±0.3 a	0.3±0.3 a	1.3±1.3 a	2.3±0.7 a

Means (±SE) within a column followed by different letters indicate significant differences (LSD following ANOVA, $p \leq 0.05$)

Trap catches were counted weekly. The experiment was arranged in yard long bean fields in a randomized complete-block design (RCBD) with three replications in June-July 2012. The distance between the traps was 20 m. The blocks were at least 50 m apart and located in separate fields. The distance to the field edges was 5 m. After the yard long bean plants started flowering, the traps were placed on bamboo sticks in the fields using a wire.

Experiment 2 Delta traps baited with lure 1 or 2 and un-baited control traps were placed in a *Sesbania cannabina* field just above the crop canopy. Since the crop grew higher than the bamboo stick, the trap height was adjusted and the final trap height was about 2 m. Traps were arranged in a RCBD in four replications. The distance between individual traps was 15 m and the distance to the field edges was at least 2 m. Trap catches were counted weekly over 4 weeks.

Experiment 3 Delta traps with lure 1 and 2 and un-baited traps were additionally tested in *S. cannabina* fields outside of the AVRDC experimental area. Traps were fixed at the level of crop canopy. The individual traps were placed 20 m apart from each other. Per field, the two synthetic lures and one un-baited trap were placed in leguminous fields of Meinong (22°88′N, 120°55′E) in June 2012. The field experiment was conducted with five replications. Traps were removed and evaluated after 1 week. In Kaohsiung (22°57′N, 120°35′E), a similar experiment was conducted in three replications in July 2012. The traps were removed and checked after 2 weeks.

For a statistical analysis, total catches by each trap during the respective trapping periods for each experiment were used. Before a statistical analysis, the data were transformed to log(x+1). Analysis of variance (ANOVA) following the mean comparison Fisher's LSD test was carried out using SAS 9.2©.

Results

In the first field experiment with yard long bean, *M. vitrata* moths were only trapped in delta traps, but equal catches were recorded for the two lures tested (Table 1). Additionally, other Lepidopterans, such as *Spodoptera litura* were also caught in the traps (Table 1). When using delta traps, no *M. vitrata* moths were caught in *S. cannabina* fields. However, several different Lepidopteran non-target species were caught in traps in these fields, for example *S. litura* (Table 2). Interestingly, *S. litura* was found predominantly in traps baited only with 1 mg *EE*10,12-16:Ald (Table 1 and 2).

Table 2 Total catches of *Spodoptera litura* and other Lepidopteran non-targets per trap in *Sesbania cannabina* fields using delta traps and two lures compared to the non-target control. (AVRDC fields, July 2012; Meinong district, June 2012; Kaohsiung district, July 2012)

Field	Lure	*S. litura*	Non-target
AVRDC	*EE*10,12-16:Ald	1.5±1.0 a	0.5±0.3 a
	Ratio 100:5:5	0 a	0.5±0.3 a
	Control	0 a	0.5±0.3 a
Meinong	*EE*10,12-16:Ald	2.6±1.4 b	3.0±0.9 a
	Ratio 100:5:5	0.2±0.2 a	1.4±0.8 a
	Control	0 a	1.6±0.8 a
Kaohsiung	*EE*10,12-16:Ald	5.5±1.5 b	3.0±1.6 a
	Ratio 100:5:5	1.0±0.2 ab	1.0±0.5 a
	Control	0 a	1.3±0.4 a

Means (±SE) per field and within a column followed by a different letter indicate significant differences (LSD following ANOVA, $p \leq 0.05$)

Discussion

The first experiment revealed that the plastic funnel traps were not as effective in trapping Lepidopterans as the delta traps. However, also in the delta traps only very few *M. vitrata* moths were caught. Interestingly, the numbers of moths caught in traps baited with lure 1 (main pheromone component) or lure 2 ("Benin blend") were not significantly different, indicating that most-likely not the correct ratio of blend for the Asian population was used as bait. The trap height was irrelevant for moth trapping in the present study.

The noticeable preference of non-target *Spodoptera litura*-catches in delta traps baited with 1 mg *EE*10,12-

16:Ald is interesting, since this compound is not an identified sex pheromone component of *S. litura*. The sex pheromone blend of this noctuid moth comprises (*Z, E*)-9,11-Tetradecadienyl acetate, (*Z, E*)-9,12-Tetradecadienyl acetate, (*Z*)-9-Tetradecenyl acetate, and (*E*)-11-Tetradecenyl acetate) (Sun et al. 2002). Volatile collections and subsequent GC-MS analyses of the polyethylene vials showed no contaminations of the lures by these components.

The target moth *M. vitrata* was not caught in traps baited with lures 1 (main pheromone component) and 2 ("Benin blend") in the second and third experiments in *S. cannabina* fields. There are several explanations for this result. It is possible that it was too late in the rainy season when the *M. vitrata* population could have already dropped. Also the amount of 1 mg per lure used might be too high for attracting *M. vitrata* male moths. Successful field trap catches were conducted using lower doses such as 0.01 mg (Downham et al. 2003) and 0.1 mg (Downham et al. 2003, 2004) per lure. Another explanation would be the instability of the pheromone components, because we did not use an antioxidant in the lures to stabilize the components.

Conclusions

Delta traps trapped more Lepidopteran moths, but the trap height had no influence on catches. The synthetic lures at doses and ratios used were not attractive for *M. vitrata* males in field experiments. Since the chemical stability of the pheromone components is crucial, the lures must be prepared with antioxidants such as butylated hydroxytoluene for future experiments.

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