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Influence of Trap Design and Phenylacetaldehyde Upon Field Capture of Male and Female *Ostrinia nubilalis* (Hb.) (Lepidoptera, Pyralidae) and Other Moths*

Introduction

In early studies on Phenylacetaldehyde (PAA) as Lepidoptera attractant, Smith *et al.* (1943) discovered that the compound and other chemicals were effective in causing capture of both males and females of *Trichoplusia ni* (Hb.). Creighton *et al.* (1973) showed the capture rate of *T.ni* and other Lepidoptera species increased when PAA was combined with sex pheromone.

Surprisingly different results where reported by Flint *et al.* (1977), who found that PAA impeded oviposition by *Pectinophora gossypiella* (Saunders) in cotton. This repelling effect seemed to be related to the moth's direct contact with PAA-treated plants. The compound did not prevent egg laying on nearby untreated plants and males freely responded to pheromone-baited traps in PAA-treated plots. Cantelo and Jacobson (1979a) subsequently found that PAA was among the volatiles they extracted from corn silk. Their field trials showed that PAA attracted *Ostrinia nubilalis* (Hb.) (Lepidoptera, Pyralidae), European Corn Borer (ECB), and other insect species. They also reported that ECB was even more susceptible to the combination PAA + butanol and PAA + acethaldehyde than to PAA alone, and speculated that because 79 % of ECB captured were males, the attraction was not completely linked to egg laying.

Cantelo and Jacobson (1979b) went on to discover that PAA was also a volatile in the component of the bladder flower (*Araujia sericofera* Brot.), a plant native to South America that had for years attracted the attention of naturalists because of its ability to lure and capture Lepidoptera as well as other insects (literature cited in Cantelo and Jacobson, 1979b).

Pawar *et al.* (1983) conducted trials on extending the persistence of PAA by

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using ascorbic acid as an antioxidant. They succeeded in increasing the number of *Heliothis armigera* (Hb.) males and females captured as compared to that of PAA alone.

We report the results of field trials using PAA and ECB sex pheromone to trap ECB in cornfields of northern Italy's Bologna Province. The experiments were specifically aimed at capturing the females because trapping males with sex pheromones has not always provided reliable data predective on actual damage subsequently done by larvae. Several reasons have been adduced for poor ECB trapping performance. Instances have been reported of the unreliability of sex pheromone traps for ECB detection programs (Oluomi-Sadeghi *et al.*, 1975; Kennedy and Anderson, 1980; Thompson *et al.*, 1987; Muszkat and Melamed-Madjar, 1987). McLeod and Starrat (1978) observed a decline in male captures over time and related it to trap ageing and to formation of inhibitory or repellent substances in the synthetic lure. Struble *et al.* (1987) suspected that the presence of *Z*-9-14:Ac and *Z*-9-12:Ac in some batches of commercially prepared sex pheromone have caused erratic catches and difficulties in monitoring ECB population levels. Indeed, another inhibitor *E*-9-14:Ac was found in female extracts (Klun *et al.*, 1979) and, when added to virgin female traps, reduced male attraction (Maini and Gavioli, 1982). The issue is further complicated by the poor efficacy of the sticky as compared to water-pan and to cone traps in capturing ECB males (Webster *et al.*, 1986; Thompson *et al.*, 1987), and by the fact that ECB exhibits intraspecific pheromonal polymorphism (Klun and Cooperators, 1975; Klun and Maini, 1979; Anglade *et al.*, 1984; Roelofs *et al.*, 1985; Roelofs *et al.*, 1987; Hansson *et al.*, 1987; Peña *et al.*, 1988; Klun and Huettel, 1988; Lofstedt *et al.*, 1989). We speculated that employing a non-pheromone type of attractant such as PAA along with the two main pheromone components might be a more effective way to survey populations of ECB, in areas where ECB strains are sympatric. Such a lure mixture might also caused capture of females which could prove important for monitoring the mating status of females in a population.

Materials and methods

The field trials with PAA (Janssen, 85 % purity) began in 1984 at Medicina in Bologna Province. Four water-pan traps (30 cm in diameter) spaced 30 m apart where set 1 m above the ground on poles along the edges of cornfields on 6 August and removed on 30 August. Two were baited with PAA, at dose of 200 µl and 1000 µl + detergent in the water (5% solution); the other two with cigarette filters impregnated with the same PAA bait doses and hung 2-3 cm above the pans containing water and detergent. The traps were sampled twice a week, serviced adding water and changing the lure the 16th August.

In 1987 cone traps similar to the *Heliothis* Scentry® (Webster *et al.*, 1986) were prepared by winding a plastic screen (1 x 1 mm mesh) round a cone wire frame on top of which a removable plastic screen, acting as a containment de-

vice, was placed. At each sampling these devices (capture bags) were collected and replaced. The size of the opening at the base was 25 cm. The cone traps were hung 1 m above ground on 3 plastic poles. Eighteen cone traps were set up 20 m apart along the edges of cornfields in six blocks spaced 100 m one from the other. Strung across the lower opening of the traps was one of the following 3 kinds of bait: rubber septa of the commercially available Traptest® consisting of 0.1 mg of sex pheromone blend (97:3; *E*:*Z*-11-tetradecenyl acetate) (Klun and Cooperators, 1975), same rubber septa + PAA (1.5 g in cotton wick), or 1.5 g PAA alone on a wick.

In 1988 the following traps were set at Zenerigolo near Bologna and their performance was compared: the Traptest® traps baited with 0.1 mg of the 97:3 sex pheromone blend, cone traps baited with 0.1 mg pheromone blend + PAA (1.5 g in felt fibre dispenser, Capizzi *et al.*, 1986), same trap with only pheromone blend, PAA alone and unbaited traps. PAA was stabilized with Irganox 1010. All the traps were set on 17 June and left until 22 September, and checked every 3-4 days. At each sampling the moths collected in the removable capture bag were determined and the ECB females' corpora bursae were examined. The trial employed a linear randomized block design of the five treatements with six replications. Weekly trap captures were transformed to $\sqrt{x+0.5}$ and analyzed with a two-way analysis of variance (ANOVA) followed by Duncan's multiple range test. The three-year data comparison between a pair of means were analyzed using a one-way analysis of variance (ANOVA).

Results and discussion

The 1984 and 1987 trials were preliminary. In 1984, PAA captured almost as many ECB females as males: 34.75 ♀♀/week; 30.00 ♂♂/week (Fig. I). Neither PAA concentration (32.50 ECB moth/week for 200 µl and 32.25 ECB moths/week for 1000 µl) nor dispenser, i.e. filter/water, (37.25 and 27.50 ECB moth/week respectively) showed significant difference in adult capture rate. In 1987, PAA mainly attracted females (Fig. I), whereas the total number of trapped adults in the cone traps baited with PAA was significantly lower than in the pheromone and pheromone + PAA baited traps (Tab. 1).

The 1988 data show that ECB females, whether virgin or not, were significantly attracted by PAA as compared to control (Tab. 2). Male captures were significantly higher with the cone traps than with Traptest® for the same bait (Fig. II, Tab. 2). Captures by sticky traps were few and did not significantly differ from those by unbaited trap cones (Tab. 2). Nor did the PAA-baited traps show significant capture differences from unbaited traps for ECB males. Yet Cantelo and Jacobson (1979a; 1979b) showed that PAA attracts males, albeit to a lesser extent than the sex pheromone, which accounted for 79 % of the captured adults. Unlike the Maryland results, our 1987 sex ratio findings (Fig. I) show that female captures by PAA always registered significantly higher values. The slight divergence in our results may be attributed mainly to differences in

Tab. 1 - Average number of ECB captures/week (x ± s.e.) in 1987. Means within rows followed by the same letters do not differ significantly at $P < 0.05$ (Duncan's multiple range test). Data transformed to $\sqrt{x+0.5}$.

ECB moths	Cone traps		
	E:*Z*(97:3)	PAA + *E*:*Z*(97:3)	PAA
♀♀	0.09 ± 0.05 a	1.05 ± 0.18 b	0.98 ± 0.16 b
♂♂	8.17 ± 1.48 a	6.57 ± 2.29 a	0.40 ± 0.09 b

sampling period, agroecosystem and action site (Derozari *et al.*, 1977). This would also hold true for the sex ratio differences in captures, which could even be affected here by vegetation and action site. Another influence, as well as competition, might be due to the high male captures by the pheromone-baited traps, although the spacing between traps and their randomized layout tend to exclude this.

Efficacy of traps baited with PAA and other plant volatiles alone or plus sex pheromone components must be further investigated. The increased catches males and females might allow better resolution of ECB flights (Fig. II). Enhancement of *Anthonomus grandis* Boh. captures by green leaf volatiles added to its aggregation pheromone was recently reported (Dickens *et al.*, 1990). In this case use of plant volatiles will reduce the amount of pheromone needed in traps and thereby survey costs will be reduced.

Creighton *et al.* (1973) conclude that PAA attractiveness to the male of dif-

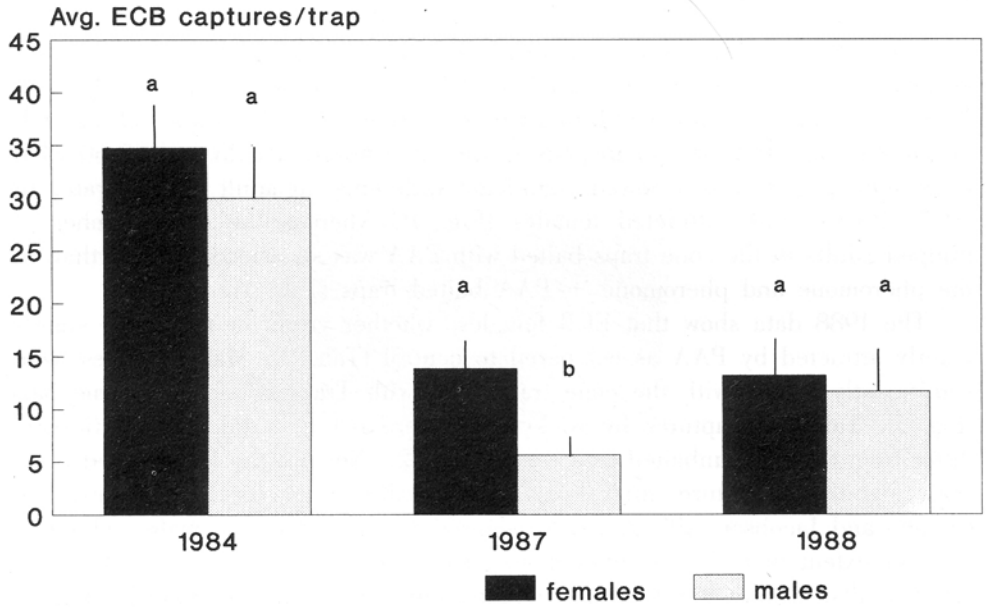

Fig. I - Catches of ECB females and males by PAA baited traps. Bars indicated by the same letters are not statistically different at $P < 0.05$ (ANOVA).

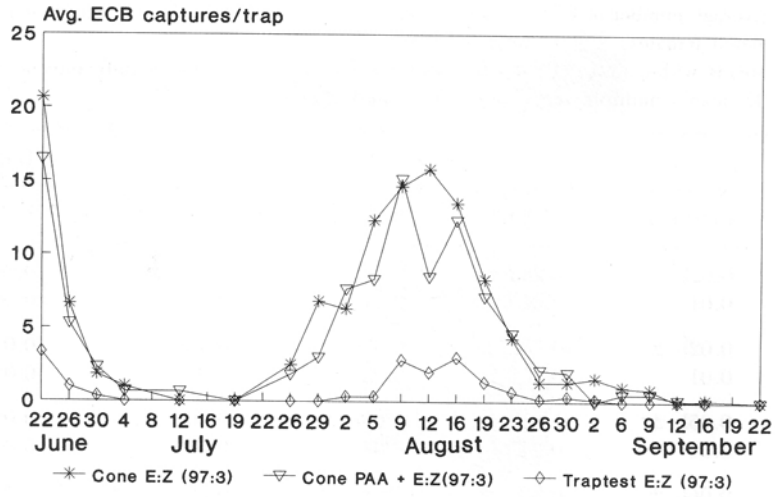

Fig. II - Catches of ECB males by sex pheromone baited traps and males and females by PAA + sex pheromone baited traps.

ferent species of moth could not be judged precisely because some males may have been attracted to virgin females moths that were present in the traps. In our experiments it is unlikely that females trapped with PAA can attract males because it is known that if ECB females are not provided drinking water, they are not able to call (Maini, unpublished data).

The cone traps baited with sex pheromone can provide more detailed information on the flight of ECB than can Traptest® with the same bait and,

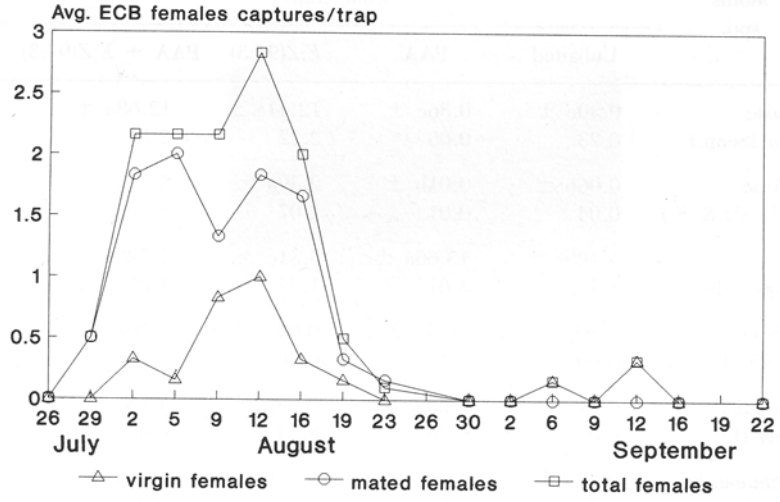

Fig. III - Catches of ECB females by PAA baited cone traps.

Tab. 2 - Average number of ECB captures/week (x ± s.e.) in 1988. v♀ = virgin females, m♀ = mated females, ♀♀ = total females.
Means within rows followed by the same letters do not differ significantly at $P < 0.05$ (Duncan's multiple range test). Data transformed to $\sqrt{x+0.5}$.

ECB moths	Cone traps				Traptest®
	Unbaited	PAA	*E*:*Z*(97:3)	PAA + *E*:*Z*(93:7)	*E*:*Z*(93:7)
v♀	0.02b ± 0.01	0.26a ± 0.04	0.01b ± 0.01	0.22a ± 0.07	0.00b ± 0.00
m♀	0.02b ± 0.01	0.73a ± 0.20	0.03b ± 0.02	0.46a ± 0.09	0.01b ± 0.01
♀♀	0.05b ± 0.01	1.01a ± 0.24	0.05b ± 0.03	0.70a ± 0.15	0.01b ± 0.01
♂♂	0.06b ± 0.06	0.88b ± 0.25	10.05a ± 3.84	6.89a ± 1.28	1.19b ± 1.19

when PAA is added to the bait, even data on the presence of females can be obtained (Fig. III). The latter are very important in determining the actual number of egg-laying females on a crop, e.g. sweet pepper which can be attacked by

Tab. 3 - Average number of captures/week of Lepidoptera species in the 1988 trials. Means within rows followed by the same letters do not differ significantly at $P < 0.05$ (Duncan's multiple range test). Data transformed to $\sqrt{x+0.5}$.

Moths spp.	Cone traps				Traptest®
	Unbaited	PAA	*E*:*Z*(97:3)	PAA + *E*:*Z*(97:3)	*E*:*Z*(97:3)
Pyrausta aurata (Scop.)	0.30c ± 0.23	0.36c ± 0.05	12.41a ± 2.22	12.68a ± 2.52	4.61b ± 1.29
Sitochroa palealis (D.& S.)	0.06b ± 0.04	0.01b ± 0.01	2.39a ± 1.07	2.51a ± 0.79	0.10b ± 0.06
Udea ferrugalis (Hb.)	5.12bc ± 1.71	15.66a ± 3.01	3.31c ± 1.34	7.72b ± 1.67	0.13d ± 0.04
Sitochroa verticalis (L.)	0.00b ± 0.00	0.75a ± 0.12	0.00b ± 0.00	0.80a ± 0.18	0.00b ± 0.00
Autographa gamma (L.)	0.11b ± 0.05	3.68a ± 0.76	0.25b ± 0.14	4.63a ± 0.47	0.00b ± 0.00
Macdunnoughia confusa Stph.	0.13b ± 0.06	1.05a ± 0.39	0.00b ± 0.00	1.29a ± 0.36	0.00b ± 0.00

ECB at different times depending on cultivar lateness or the crops surrounding it (Maini and Burgio, 1989).

In the course of our study, we observed attraction for the following additional Lepidopteran species: *Udea ferrugalis* (Hb.), *Sitochroa verticalis* (L.), *Autographa gamma* (L.), *Macdunnoughia confusa* (Stph.) (Tab. 3). The males of *Pyrausta aurata* (Scop.) and *Sitochroa palealis* (D.& S.) are attracted by the 97:3 (*E*:*Z*-11-14:Ac). PAA alone proved to be an effective attractant of *S. verticalis*, *A. gamma* and *M. confusa*. However these moths probably can be better lured using the known sex attractants (Arn *et al.*, 1986). The combination of PAA and sex pheromone might also be used for female detection of these Lepidoptera species.

Data in table 3 also showed that PAA alone might be useful as bait to detect the presence of *U. ferrugalis*. This polyphagous insect is known to be harmful to soybean (Zandigiacomo, 1988) but its sex pheromone is unknown.

A screening of other plant borne volatiles for attractant qualities could lead to substances even more effective than PAA.

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SUMMARY

European corn borer moth (ECB) *Ostrinia nubilalis* (Hb.) (Lepidoptera, Pyralidae) detection employing sex pheromone traps has proved difficult in several cases. Trap design, sex pheromone intraspecific pheromonal polymorphism, improper pheromone concentrations and the presence of inhibitory components in the baits are among the factors known to cause poor capture efficiency of ECB male moths.

The compound Phenylacetaldehyde (PAA), a known attractant for both ECB sexes was used to bait cone traps in cornfields in Bologna Province. Comparisons were made between sex pheromone sticky traps Traptest® (0.1 mg, 97:3, *E*:*Z*-tetradecenyl acetate) cone traps (Scentry® like) baited with the same sex pheromone blend, PAA (1.5 g in felt fibre dispenser) + sex pheromone, and PAA alone.

Both virgin and mated females were caught in PAA-baited cone traps. Sex pheromone baited sticky traps were less effective than baited cone traps. The addition of PAA to sex pheromone in the cone traps can provide data on the presence of females. Captures of males were neither reduced nor enhanced when traps were baited PAA and pheromone. PAA also proved attractive to *Udea ferrugalis* (Hb.), *Sitochroa verticalis* (L.), *Autographa gamma* (L.) e *Macdunnoughia confusa* (Stph.) but not for *Pyrausta aurata* (Scop.) and *S. palealis* (D.& S.).

Influenza del tipo di trappola e della fenilacetaldeide sulle catture di maschi e femmine di *Ostrinia nubilalis* (Hb.) (Lepidoptera, Pyralidae) ed altri Lepidotteri

RIASSUNTO

L'impiego delle trappole sessuali per l'avvistamento di *Ostrinia nubilalis* (Hb.) (Lepidoptera, Pyralidae) ha mostrato in molti casi diverse difficoltà. In particolare il tipo di trappola, il polimor-

fismo feromonico intraspecifico, le errate concentrazioni e la presenza di inibitori nella miscela, sono fra i principali fattori conosciuti che possono causare una scarsa efficienza di cattura di maschi del fitofago.

La fenilacetaldeide (PAA), un attrattivo di entrambi i sessi di *O. nubilalis*, è stato utilizzato come innesco in trappole a cono di rete in campi di mais della provincia di Bologna. Sono state confrontate fra loro Traptest® a colla innescate con 0,1 mg di 97:3 *E*:*Z*-tetradecenil acetato, trappole a cono di rete (tipo Scentry®) con la stessa miscela feromonica, PAA (1,5 g in dispenser di feltro) + feromone, e PAA da sola.

Le trappole a cono di rete innescate con PAA si sono mostrate attrattive nei confronti delle femmine vergini e fecondate di *O. nubilalis*. Le trappole a cono sono state significativamente più attrattive delle Traptest® innescate con la stessa miscela feromonica. L'aggiunta di PAA al feromone nelle trappole a cono ha permesso la raccolta di dati inerenti alla presenza delle femmine del Lepidottero. La cattura dei maschi non è stata comunque influenzata dall'aggiunta della PAA nelle trappole a cono innescate con feromone. La PAA si è mostrata attrattiva anche nei confronti dei seguenti Lepidotteri: *Udea ferrugalis* (Hb.), *Sitochroa verticalis* (L.), *Autographa gamma* (L.) e *Macdunnoughia confusa* (Stph.), ma non per *Pyrausta aurata* (Scop.) e *S. palealis* (D.& S.).

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