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BOTH SEXES OF THE TRUE ARMYWORM (LEPIDOPTERA: NOCTUIDAE) TRAPPED WITH THE FEEDING ATTRACTANT COMPOSED OF ACETIC ACID AND 3-METHYL-1-BUTANOL

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ABSTRACT

Male and female true armyworm moths, *Pseudaletia unipuncta* (Haworth), were captured in traps baited with the combination of acetic acid and 3-methyl-1-butanol and placed near fields of corn (*Zea mays*). In a comparison of these chemicals presented individually and together, significantly greater numbers of moths were captured in traps baited with acetic acid and 3-methyl-1-butanol, compared to traps baited with acetic acid alone or traps baited with 3-methyl-1-butanol alone. Eighty percent of the female true armyworm moths captured in September in traps baited with acetic acid and 3-methyl-1-butanol were unmated and immature (no eggs and with considerable fat body). The remaining 20% of those females captured were mated and had some ovarian development. These results demonstrate attraction of male and female true armyworm moths to the combination of acetic acid and 3-methyl-1-butanol and provide a new means of trapping females of this species.

RESUMEN

Machos y hembras de la polilla del gusano soldado, *Pseudaletia unipuncta* (Haworth), fueron capturados en trampas cebadas con la combinación de ácido acético y 3-metil-1-butanol y colocadas cerca de campos de maíz (*Zea mays*). En una comparación de estos químicos presentados individualmente y en conjunto, cantidades significativamente mayores de polillas fueron capturadas en trampas cebadas con ácido acético y 3-metil-1-butanol, en comparación con las trampas cebadas solamente con ácido acético o las trampas cebadas solo con 3-metil-1-butanol. Ochenta por ciento de las polillas hembras del gusano soldado capturadas en septiembre en las trampas cebadas con ácido acético y 3-metil-1-butanol eran inmaduras y no se habían apareado (sin huevos y con considerable tejido graso). El 20% restante de esas hembras capturadas se habían apareado y tenían algún desarrollo ovárico. Estos resultados demuestran la atracción de los machos y la hembra de la polilla del gusano soldado a la combinación de ácido acético y 3-metil-1-butanol y proporciona un nuevo significado a la captura de hembras de esta especie.

During trapping studies of volatile chemicals from fermented solutions of molasses, the combination of acetic acid and 3-methyl-1-butanol was found to attract males and females of three species of Noctuidae (Lepidoptera) that are tree fruit pests in Washington: *Lacanobia subjuncta* (Grote & Robinson), *Mamestra configurata* Walker, and *Xestia c-nigrum* (L.) (Landolt 2000). Subsequently, results of season-long sampling near Yakima, Washington indicated that acetic acid with 3-methyl-1-butanol may be attractive to many species of noctuid moths, including the true armyworm, *Pseudaletia unipuncta* Haworth, (Landolt & Hammond 2001).

The true armyworm is a serious defoliating pest of a number of crops in North America, including corn (*Zea mays*), small grains, and pasture grasses (Pfadt 1978). A female-produced sex pheromone for *P. unipuncta* was identified by McDonough et al. (1980) and Steck et al. (1982) and is used in monitoring traps for this insect. However, there are no lures that attract females of this species. This study was undertaken to determine if males and females of the true armyworm are indeed attracted to the combination of acetic acid and 3-methyl-1-butanol, as was suggested by Landolt & Hammond (2001). We report here the results of trapping experiments that test that hypothesis. These experiments were conducted in an area known to have an infestation of true armyworm in corn and were set up in response to complaints by growers of armyworm damage to corn. Additionally, data was obtained confirming attraction of *L. subjuncta* to this lure.

MATERIALS AND METHODS

Two trapping experiments were conducted in September and October 2000 in Hamilton County, Washington, in an area of irrigated row crops, predominantly corn, alfalfa (*Medicago sativa*), and potato (*Solanum tuberosum*), as well as plantings of hybrid trees of the genus *Populus*. The Universal moth trap (Unitrap, IPM Technologies, Portland, OR) was used in both experiments. Each trap contained a 4 cm^2 piece of Vaportape (Hercon, Inc., Emigsville, PA). All attractants tested were dispensed from 15 ml polypropylene vials, each containing 3 cotton balls and each with a 3.3 mm hole in the lid. This system was used for trapping *L. subjuncta* moths with the same attractant (Landolt & Alfaro 2001). Traps were hung from stakes at a height of 1.0 m and were placed 10 to 20 m apart around the periphery of a field of corn.

The first experiment compared moths captured in 10 unbaited traps with those captured in 10 traps baited with acetic acid and 3-methyl-1-butanol. Baited traps contained two 15 ml vials, one containing 5 ml of glacial acetic acid (Baker Chemical, Phillipsburg, NJ) on 3 cotton balls and the other containing 5 ml of 3-methyl-1-butanol (Aldrich Inc., Milwaukee, WI) on 3 cotton balls. Baited and unbaited traps were paired in their placement outside the periphery of an irrigated corn circle. These were set up on 13 September and were checked 15 and 18 September. Treatment and control positions were changed on Sept 15. Trap catch data were compared by a paired *t* -test (DataMost 1995).

The second trapping experiment consisted of 5 replicate randomized blocks of 4 treatments. Those 4 treatments were 1) no lure, 2) acetic acid, 3) 3-methyl-1-butanol, and 4) acetic acid in one vial and 3-methyl-1-butanol in a second vial. These were set up on 29 September and were checked on 2 and 5 October. Positions were randomized initially and on 2 October. Trap catch data were subjected to an ANOVA and means were separated by Tukey's test (DataMost 1995).

One hundred female *P. unipuncta* and 50 female *L. subjuncta* captured in the first trapping test were dissected to determine the number of spermatophores in mated females and the reproductive status of moths captured. Fifty female *P. unipuncta* captured in the second test were also dissected. Because the second test was three weeks later than the first test, we were interested in determining if the moths that responded had changed in terms of reproductive maturity. Females were scored from 1 to 4 for reproductive status, with #1 being unmated and immature (no eggs, abundant fat body), # 2 being mated and immature (<10 eggs and abundant fat body), #3 mated and mature (mated, >10 eggs), and #4 mated and senescent.

Results

Totals of 458 male and 535 female *P. unipuncta* were captured in the first experiment. Significantly greater numbers of both male (t = 4.88, df = 19, P < 0.01) and female (t = 4.80, df = 19, P < 0.01) *P. unipuncta* were captured in baited traps compared to unbaited traps in the first experiment (Table 1), with a sex ratio of 0.85 males to 1.0 females. Significantly greater numbers of both male (t = 5.77, df = 19, P < 0.01) and female (t = 5.52, df = 19, P < 0.01) *L. subjuncta* were captured in baited traps compared to unbaited traps in the first experiment (Table 1). Totals of 83 male and 127 female *L. subjuncta* were captured with a sex ratio of 0.65 males to 1.0 female. Significantly greater numbers of western yellowstriped armyworm moths, *Spodoptera praefica* (Grote), were captured in baited traps compared to unbaited traps (t = 3.07, df = 19, P < 0.01). A total of 26 male *S. praefica* were captured and no females were captured in this test. Additionally, small numbers of spotted cutworm moths (*X. c-nigrum*) and bertha armyworm moths (*M. configurata*), were captured in baited traps, but these numbers were not significant in comparison to unbaited traps.

In the first experiment, 80% of female *P. unipuncta* moths captured in baited traps and dissected were unmated and had little or no ovarian development (Table 2). The remainder were mated, and possessed developing or developed ovaries with eggs. Female *L. subjuncta* captured in baited traps were primarily mated, and included undeveloped ovaries as well as ovaries with eggs (Table 2). The mean number of spermatophores per mated female *P. unipuncta* was 1.80 ± 0.19 (Table 2), with a range of 1 to 3 spermatophores. The mean number of spermatophores per mated female *L. subjuncta* was 1.38 ± 0.10 (Table 2), with a range of 1 to 3 spermatophores.

The distribution of dissected female *P. unipuncta* within the categories of reproductive development (Table 2) was significantly different than the distribution of dissected female *L. subjuncta* (2 × 3 contingency table, χ^2 = 44.2, P < 0.001). A total of 314 male and 251 female *P. unipuncta* moths were captured in the second experiment, comparing the attractiveness of the combination of acetic acid and 3-methyl-1-butanol to

TABLE 1. MEAN (±SE) NUMBERS OF MOTHS CAPTURED IN TRAPS BAITED WITH A MIXTURE OF ACETIC ACID AND 3-METHYL-1-BUTANOL AND IN UNBAITED TRAPS. SEPT. 2000.[A]

	Males		Females	
Moth Species	Baited Traps	Unbaited Traps	Baited Traps	Unbaited Traps
P. unipuncta	22.9 ± 4.7 b	0.1 ± 0.1 a	26.8 ± 5.6 b	0.0 ± 0.0 a
Lacanobia subjuncta	6.4 ± 1.2 b	0.0 ± 0.0 a	4.2 ± 0.7 b	0.0 ± 0.0 a

[A]Within a species and within a sex, means followed by the same letter are not significantly different by a paired t test at P > 0.05.

TABLE 2. MEAN (±SE) NUMBER OF SPERMATOPHORES PER FEMALE CAPTURED IN TRAPS BAITED WITH A MIXTURE OF ACETIC ACID AND 3-METHY-1-BUTANOL AND THE PERCENTAGES OF THOSE FEMALES CAPTURED THAT WERE EITHER UNMATED AND IMMATURE (CATEGORY 1), WERE MATED AND IMMATURE (CATEGORY 2), WERE MATED AND MATURE (CATEGORY 3) AND WERE MATED AND SENESCENT (CATEGORY 4).

Moth	Mean (±SE) no. spermatophores	n	Reproductive status: % in category			
			1	2	3	4
Test 1						
Pseudaletia unipuncta	1.80 ± 0.19	100	80	7	13	0
Lacanobia subjuncta	1.38 ± 0.10	50	24	32	44	0
Test 2						
Pseudaletia unipuncta	1.50 ± 0.33	50	82	14	4	0

each chemical separately. Significantly more *P. unipuncta* moths were captured in traps baited with the combination of both chemicals, compared to the unbaited control traps or to traps baited with individual chemicals (Table 3), and there were no differences between captures in traps baited with single component lures and in unbaited traps. Additionally, small numbers of *L. subjuncta*, *X. c-nigrum* and alfalfa looper moths *Autographa californica* (Speyer) were captured in traps baited with the combination of acetic acid and 3-methyl-1-butanol. However, these were not statistically significant, compared to unbaited traps. Eighty-four percent of the 50 female *P. unipuncta* moths dissected were unmated and immature, with no eggs present (Table 2). Mated *P. unipuncta* moths captured in this test possessed 1.50 ± 0.33 spermatophores per female.

DISCUSSION

The results of these experiments clearly demonstrate the attractiveness of the feeding attractant comprised of acetic acid and 3-methyl-1-butanol to both sexes of the true armyworm *P. unipuncta*. Although this attractiveness was suggested by Landolt & Hammond (2001), that study was not designed to demonstrate such attractiveness statistically. Additionally, this work confirms the attractiveness of this lure to males and females of *L. subjuncta* (Landolt 2000), a pest of apple in Washington and Oregon (Landolt 1998), and to males of *S. praefica*, the western yellow-striped armyworm.

The results of the second experiment indicate a strong synergism of acetic acid and 3-methly-1-butanol in attracting *P. unipuncta*. This is evidenced by the large numbers of moths captured in traps baited with the combination of chemicals in comparison to small numbers captured in traps baited with acetic acid or 3-methyl-1-butanol alone. This strong enhancement or synergy is in contrast to the response of *L. subjuncta* to these chemicals. The combination of acetic acid and 3-methyl-1-butanol attracts more *L. subjuncta*, *M. configurata* and *X. c-nigrum* to traps, compared to acetic acid alone or 3-methyl-1-butanol alone, but the enhancement is quite modest, perhaps doubling or tripling the response (Landolt 2000, Landolt & Alfaro 2001), whereas the enhancement here of *P. unipuncta* to the combination of chemicals was about 30 times the response to either chemical alone.

This work provides an alternative chemical attractant for monitoring *P. unipuncta*. The sex pheromone of this insect was identified by McDonough et al. (1980) and Steck et al. (1982) and constitutes a strong attractant that can be used in traps to monitor the presence of males (Kamm et al. 1982). The feeding attractant comprised of acetic acid and 3-methyl-1-butanol lures both males and females and may be useful in research on the activities of females of this widespread pest moth, as well as to indicate the arrival or emergence of females on crops at risk.

TABLE 3. MEAN NUMBERS OF *PSEUDALETIA UNIPUNCTA* MOTHS CAPTURED IN TRAPS BAITED WITH EITHER ACETIC ACID, 3-METHYL-1-BUTANOL OR THE COMBINATION OF ACETIC ACID AND 3-METHYL-1-BUTANOL.

Sex	Control	Acetic Acid	3-Methyl-1-Butanol	Combination
Male	0.2 ± 0.1 a	0.6 ± 0.3 a	1.2 ± 0.4 a	26.4 ± 8.4 b
Female	0.1 ± 0.1 a	0.0 ± 0.0 a	0.8 ± 0.4 a	40.7 ± 7.4 b

[a]Means within a row followed by the same letter are not significantly different by Tukey's test at P ≤ 0.05.

The reproductive and mating status of females trapped in this study is noteworthy. First, a high percentage of female *P. unipuncta* moths captured were unmated and did not have developed eggs in the ovaries. *Pseudaletia unipuncta* is at times a migratory species (Beirne 1971, McNeil 1987) and it is possible that most adults present in Washington in late summer and early autumn may delay mating and reproductive development in preparation for a migration. Female onset of pheromone production is delayed in this insect by autumn photoperiods (Delisle & McNeil 1986, 1987) and most females captured in light traps in autumn are unmated and have immature ovaries (McNeil 1987). Female *P. unipuncta* that delay mating and reproductive development until after a migratory flight (McNeil 1987) may have a strong need to obtain additional nourishment prior to those flights, hence the response to our feeding attractant.

The mating and reproductive status of female *L. subjuncta* moths captured included many that were mated and with some ovarian development. This was similar to that reported by Hitchcox (2000) for *L. subjuncta* moths sampled with the same chemical attractant, during both the first and second flights of this insect. It is not known if these trapping results with *L. subjuncta* and with *P. unipuncta* reflect the reproductive stages of moths that respond to the feeding attractant or if they reflect the population of moths present at the time of the study. If however, female moths generally respond when they are reproductively immature, such an attractant may be useful as a means of removing moths before they oviposit, to effect population reductions on crops.

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