ATTRACTION OF TOBACCO BUDWORM MOTHS (LEPIDOPTERA: NOCTUIDAE) TO JAGGERY, A PALM SUGAR EXTRACT

P. J. LANDOLT[1] AND E. R. MITCHELL[2]
United States Department of Agriculture, Agricultural Research Service

[1]Yakima Agriculture Research Laboratory, 5230 Konnowac Pass Road
Wapato, WA 98951

[2]Center for Medical, Agricultural and Veterinary Entomology, 1700 SW 23rd Dr.
Gainesville, FL 32604

ABSTRACT

Male tobacco budworm, *Heliothis virescens* Fab., moths released into a field cage were recaptured in traps baited with aged 10% jaggery, a palm sugar extract. Both male and female tobacco budworm moths were attracted to aged 10% jaggery in a flight tunnel, exhibiting oriented flights ending in contact with the bait. Although the bait was initially not attractive either to females in a flight tunnel or to males in a field cage, it subsequently became attractive after one week and increased in attractiveness for up to 24 days after it was made.

Key Words: attractant, feeding, *Heliothis virescens*, trap, behavior, sugar

RESUMEN

Machos adultos del gusano del tabaco, *Heliothis virescens* Fab., liberados en una jaula de campo fueron recapturados en trampas cebadas con 10% de jaggery envejecido, un extracto de azúcar de palma. Tanto hembras como machos adultos fueron atraídos por el cebo en un túnel de vuelo, y ambos mostraron vuelos orientados terminando en el contacto con el cebo. A pesar de que el cebo inicialmente no fue atractivo a las hembras en el túnel de vuelo, o a los machos en la jaula de campo, éste se tornó atractivo después de una semana e incrementó su atractividad hasta los 24 días de haber sido preparado.

The tobacco budworm, *Heliothis virescens* (Fab)., is a pest of several agricultural crops in North America, including tobacco and cotton. The principal means of monitoring the presence of tobacco budworm is a female sex pheromone blend that is attractive to males (Sparks et al. 1979, Ramaswamy et al. 1985). However, such a method is ineffectual in fields treated with female sex pheromone as a mating disruptant. Also, the relationship between numbers of males captured in pheromone traps and either population levels or crop damage is not clear. Additional attractants, particularly if effective for females, would be useful under such circumstances.

A variety of moths are attracted to sweet materials, presumably as a source of adult nutrition. Sugar-rich concoctions often are used by moth and butterfly collectors (Holland 1903, Sargent 1976). Molasses solutions have been used to trap oriental fruit moth, *Grapholita molesta* (Busck), (Frost 1926) and codling moth, *Cydia pomonella* (L), (Eyer 1931) in tree fruit orchards. Many noctuid moths are attracted to sugar baits (Norris 1936), although documentation of which species are attracted is lacking. Frost (1928) captured 23,574 noctuid moths in 300 pails containing sugar baits set out for oriental fruit moth, but did not identify them below the family level. Poisoned sweet baits were used for control of corn earworm, *Helicoverpa zea* (Boddie), during the 19th century (Ditman & Cory 1933 and references therein). The grass looper, *Mocis latipes* Guenee, can be captured in traps baited with solutions of molasses or jaggery (Landolt 1995). Jaggery is an unrefined sugar made from palm sap, used asa cooking sweetener in some areas of subtropical and tropical Asia. Landolt (1995) also reported the capture of 13 additional species of Noctuidae in glass traps baited with jaggery or molasses solutions in Florida.

There are no reports of captures of tobacco budworm moths in traps with baits containing sugars or sugar-based materials. However a great number of species of Noctuidae likely are attracted to sugar baits (Norris 1936), and most Noctuidae captured in traps baited with sugar-rich materials have not been identified (e.g., Frost 1928). The tobacco budworm moth feeds at flowers, extrafloral nectaries, artificial sugar sources, and grass heads (Lingren et al. 1977, Ramaswamy 1990) and may be attracted to sugar baits.

We report here the attraction of male and female tobacco budworm moths to solutions of jaggery, and we also determined the optimum age of the bait for attractiveness to moths in a flight tunnel. This work demonstrates the upwind orientation of tobacco budworm in response to food baits and provides a convenient assay system for pursuing the isolation and identification of attractive volatile chemicals emanating from sugar baits. It is hoped that such compounds may be useful as attractants for tobacco budworm as well as other pestiferous species of moths.

MATERIALS AND METHODS

Insect Rearing and Handling

Tobacco budworm pupae were obtained from the laboratory colony maintained at the Gainesville, Florida, United States Department of Agriculture, Agricultural Research Service laboratory. Pupae were sorted by sex and were held in screened cages ($25 \times 25 \times 25$ cm) for adult emergence. Pupae were moved to new cages daily to provide moths of discrete age groups. A water jar was placed on the top of each cage, and each cage was provisioned with a 60 ml paper cup containing water-soaked cotton balls. Males and females were held in separate environmentally-controlled rooms at 24°C, 60-80% RH and a 14:10 (L:D). photoperiod with lights off at 0800 and on at 1800 hours (E.S.T).

Field Cage Bioassay

An initial test of tobacco budworm moth response to jaggery (Indian Kolhapur Jaggery, House of Spices Inc., Jackson Heights, NJ) was conducted in 2 large cylindrical cages, each 2.2 m in height and 2.7 m in diameter (Calkins & Webb 1983), which were set up in an area of lawn largely beneath the shade of a live oak tree. Pairs of glass McPhail traps (Newell 1936) were hung from the ceiling of each cage, about 0.5 m north and 0.5 m south of the center of the field cage. Traps were hung by a wire with the trap opening 20 cm below the cage ceiling. One of each pair of traps in a cage was baited with 200 ml of 10% jaggery in deionized water (5 to 16 days old) and the other trap was baited with 200 ml of deionized water. From 20 to 30 male tobacco budworm moths (3 to 5 days of age) were released into a field cage in late afternoon, and the numbers of moths captured in traps were counted the following morning. Jaggery bait was 5 to 16 days old when placed in the field cages. This assay was conducted 20 times, with jaggery bait reused for replicates. Jaggery-baited and control traps were alternated in position with each assay replicate for both field cages. Mean trap catch data, combined for all bait ages, were analyzed by Students t-test to determine if the catches of moths in treatment and control traps were significantly different. Catch data for jaggery-baited traps were also evaluated in comparison to bait age by regression analysis.

Flight-Tunnel Bioassays

Two experiments were conducted using a flight tunnel to evaluate tobacco budworm moth responses to jaggery. The flight tunnel and room were described by Landolt and Heath (1987). Moths were tested during the 3rd through 5th hours of the 10 h scotophase, and they were placed in the flight tunnel room 30 min before the bioassays. Moths were tested individually. They were released from a plastic vial near the center of the downwind end of the flight tunnel and were given 2 min to respond to test materials placed at the upwind end of the flight tunnel. Moths were scored for upwind oriented flights within the odor plume and for proximity or contact with the odor source following plume tracking. The baits tested were 10% solutions of jaggery made up as 400 ml batches and placed in open glass jars in a laboratory fume hood until used. For flight tunnel assays, 200 ml of solution were poured into a 9 cm plastic petri dish supported by a ring and ring stand. A paper towel was hung into the middle of the dish to act as a wick, increasing the surface area of the solution.

The first flight tunnel experiment was a demonstration of male and female tobacco budworm attraction to aged jaggery. Three to four-day old unfed females were tested to either a200 ml batch of aged (12 to 28 days) 10% jaggery in water or to 200 ml of water alone. Ten female moths were sequentially tested for a response to water, followed by ten females sequentially tested for response to jaggery. This experiment was conducted on five different days, with water presented first in 2 trials, and jaggery presented first in 3 trials. This experiment was repeated with males, but on 7 different days. The treatment sequence (water and jaggery) was also alternated between replicates in this experiment. Attraction response data (attraction is upwind oriented flight and contact with the bait) were analyzed by Student's t-test, after transformation to percentages of moths tested within each data set.

Because microbial fermentation may be a determining factor in the attractiveness of food baits to many lepidopterans (Norris 1936), a second flight tunnel experiment was conducted to evaluate the effect of the age of the jaggery bait on its attractiveness to female tobacco budworm. It is expected that colonization and growth of microbes in baits, and resultant changes in odorants released from baits, occur over time. Attractiveness to bait may then increase with time, as microbes and their metabolic byproducts increase in abundance. This experiment was conducted as two separate series of bait ages: a short series and a long series. The short series consisted of baits held for 0, 3, 6, 9, and 12 days in a fume hood in the laboratory. Baits were made every 3 days and bioassays were conducted on 6 different days when baits of all age cohorts were available simultaneously. The long series consisted of baits held for 0, 6, 12, 18, and 24 days. Similarly, these were made every 6 days and bioassays were conducted on 6 different days when baits of all age cohorts were available simultaneously. Every time a series of bait ages was tested in the flight tunnel, five females were tested per treatment (bait age). Thirty females were tested per treatment over the course of the replicates. The treatment sequence was altered daily over the 6 days that the test was replicated. Response data for the long series was subjected to regression analysis for relationship between bait age and moth response.

RESULTS

Male tobacco budworm moths were captured only in traps baited with 10% jaggery placed in field cages. Mean numbers of released males captured in glass McPhail traps baited with 10% aged jaggery (4.45 ± 1.5 moths per trap per day) were significantly greater than those captured in traps baited only with water (no moths captured) ($t = 3.0$, $df = 19$, $p = 0.008$). There was a significant linear regression of bait age versus numbers of male tobacco budworm captured in traps baited with jaggery ($r^2 = 0.65$, $t = 2.58$, $df = 18$, $p = 0.03$, $Y = -9.26 + 1.42X$) (Fig. 1).

Both sexes of tobacco budworm were attracted to 10% solutions of jaggery presented in the flight tunnel. Twenty-four percent of females flew upwind and contacted the jaggery bait, compared to no females responding to the control (water only) ($t = 4.71$, $df = 4$, $p = 0.009$). Twenty-seven percent of males tested flew upwind and contacted the jaggery bait compared to no males responding to the control ($t = 3.14$, $df = 6$, $p = 0.022$).

In a direct comparison of the attractiveness of jaggery bait of different ages, no female tobacco budworm moths were attracted to bait that was freshly made or was 3 or 6 days old. Nine-day old jaggery was essentially non-attractive as well. Female response to jaggery increased with bait age from 12 through 24 days old (Fig. 2), with the highest response (40%) obtained with 24 day old bait. The relationship between bait age and moth response for the long series was significant by regression analysis ($r^2 = 0.948$, $t = 5.14$, $df = 4$, $p = 0.014$, $Y = -6.3 + 1.73X$).

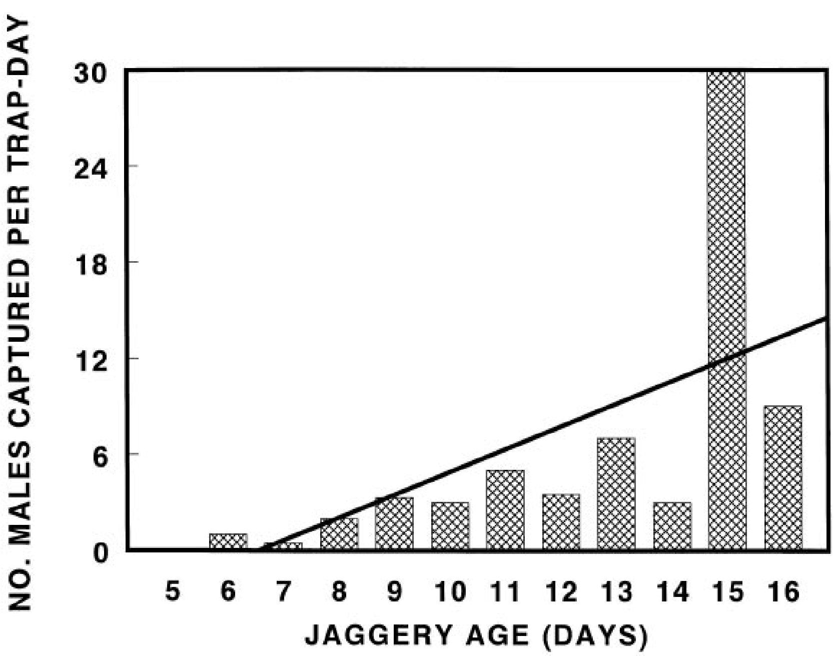

Fig. 1. Numbers of male tobacco budworm moths released into a field cage and captured in traps baited with 10% jaggery of different ages. February-March 1996.

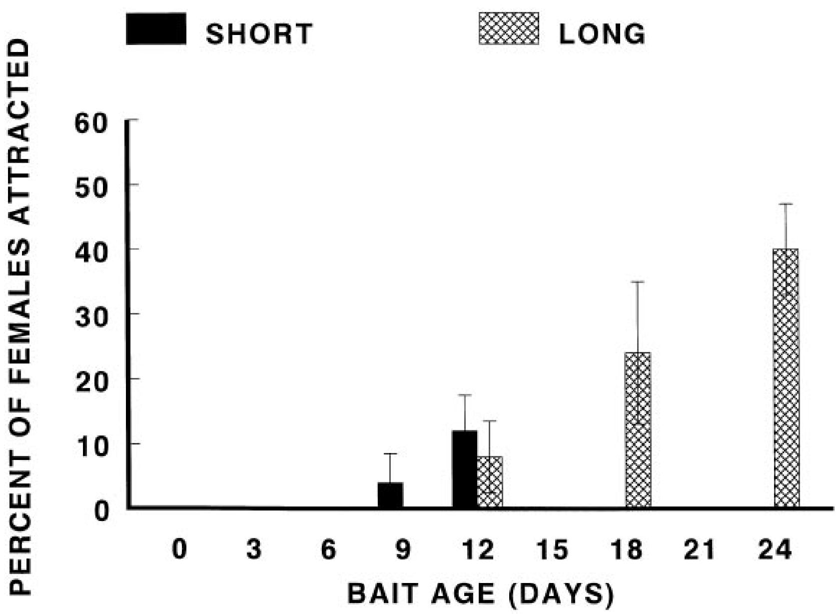

Fig. 2. Percentages (± SEM) of female tobacco budworm moths attracted to contact a pan containing 200 ml of 10% jaggery in a flight tunnel, for different ages of jaggery. The short series (solid bars) included 0, 3, 6, 9, and 12-day old baits. The long series (cross hatched bars) included 0, 6, 12, 18, and 24-day old baits.

Discussion

These results demonstrate that both sexes of tobacco budworm are attracted to fermented bait made from 10% jaggery. Both females and males were attracted to jaggery (exhibited upwind oriented flights from the release dispenser and contacted the bait) in the flight tunnel. The recapturing of male tobacco budworms in baited traps in a field cage also indicates an ability to orient to the source of odors from such baits.

This is the first report of orientation responses to food baits by *H. virescens*. Adult tobacco budworms feed at materials that are sugar rich, including flowers, extrafloral plant nectaries, and grass florets (Lingren et al. 1977, Ramaswamy 1990). There are also reports of corn earworm moths feeding at sweet baits (Ditman and Cory 1933) and at fungal-infected grass florets (Beerwinkle et al 1993), with the assumption that they are attracted to such materials. Tobacco budworm attraction to odors emanating from fermenting sugar solutions is likely a mechanism to locate the sources of such odors in order to feed.

The significant regressions of bait age versus males captured in traps in a field cage and bait age versus female response in a flight tunnel support the assumption of Norris (1936) that microbial activity is a critical factor in moth attraction to sweet baits. The grass looper, *M. latipes*, also responds optimally to sweet baits that are aged (Landolt 1995). However, 3- day old jaggery or 3-day old molasses was most effective as a trap bait for the grass looper, compared with 16 or 24 day old jaggery for the tobacco budworm. Perhaps the grass looper moths and tobacco budworm moths respond to different sets of odorants emanating from baits of different ages.

The positive results using the flight tunnel provide a convenient bioassay technique for pursuing the isolation and identification of odorants from solutions of jaggery that are attractive to tobacco budworm. The liquid bait and trap used in these experiments are too limited and inconvenient to use as a monitoring method for female tobacco budworms. The trap is heavy and fragile, and trap maintenance is time-consuming. The trap also holds a limited number of captured moths, and captured specimens may be difficult to identify if allowed to remain and decompose. For these reasons, it is considered that a formulated blend of synthetic chemicals that are attractive to tobacco budworm can be adapted to a cheaper and easier trap design for field use.

Acknowledgments

Technical assistance was provided by O. Molina and S. Lovvorn. Moths used in bioassays were provided by F. Adams, T. Nguyen, C. Greene, and N. Loman. S. Clement, K. Ward, T. W. Phillips, and D. M. Jackson critiqued an early draft of the manuscript.

References Cited

Beerwinkle, K. R., T. N. Shaver, and J. D. Lopez, Jr. 1993. Field observations of adult emergence and feeding behavior of *Helicoverpa zea* (Lepidoptera: Noctuidae) on dallisgrass ergot honeydew. Environ. Entomol. 22: 554-558.

Calkins, C. O., and J. C. Webb. 1983. A cage and support framework for behavioral tests of fruit flies in the field. Florida Entomol. 66: 512-514.

Ditman, L. P., and E. N. Cory. 1933. The response of corn earworm moths to various sugar solutions. J. Econ. Entomol. 26: 109-115.

Eyer, J. R. 1931. A four year study of codling moth baits in New Mexico. J. Econ. Entomol. 24: 998-1001.

Frost, S. W. 1926. Bait pails as a possible control for the oriental fruit moth. J. Econ. Entomol. 19: 441-450.

Frost, S. W. 1928. Continued studies of baits for oriental fruit moth. J. Econ. Entomol. 21: 339-348.

Holland, W. J. 1903. The moth book. A guide to the moths of North America. Dover Publications Inc., New York, 479 pp.

Landolt, P. J. 1995. Attraction of *Mocis latipes* (Lepidoptera: Noctuidae) to sweet baits in traps. Florida. Entomol. 78: 523-530.

Landolt, P. J., And R. R. Heath. 1987. Role of female-produced sex pheromone in behavioral reproductive isolation between *Trichoplusia ni* (Hubner) and *Pseudoplusia includens* (Walker) (Lepidoptera: Noctuidae: Plusiinae). J. Chem. Ecol. 13: 1005-1018.

Lingren, P. D., G. L. Greene, D. R. Davis, A. H. Baumhover, and T. J. Henneberry. 1977. Nocturnal behavior of four lepidopteran pests that attack tobacco and other crops. Ann. Entomol. Soc. America 70: 161-167.

Newell, W. 1936. Progress report on the Key West (Florida) fruit fly eradication project. J. Econ. Entomol. 29: 116-120.

Norris, M. J. 1936. The feeding habits of the adult Lepidoptera Heteroneura. Trans. Roy. Entomol. Soc. London. 85: 61-90.

Ramaswamy, S. B. 1990. Periodicity of oviposition, feeding, and calling by mated female *Heliothis virescens* in a field cage. J. Insect Behav. 3: 417-427.

Ramaswamy, S. B., S. A. Randle, and W. F. Ma. 1985. Field evaluation of the sex pheromone components of *Heliothis virescens* (Lepidoptera: Noctuidae) in cone traps. Environ. Entomol. 14: 293-296.

Sargent, T. D. 1976. Legion of night. The underwing moths. Univ. Massachusetts Press, Amherst, MA 222 pp.

Sparks, A. N., J. R. Raulston, P. D. Lingren, J. E. Carpenter, J. A. Klun, and B. G. Mullinix. 1979. Field responses of male *Heliothis virescens* to pheromonal stimuli and traps. Bull. Entomol. Soc. America 25: 268-274.