Using Nutrient Solutions to Trap the Almond Moth (Lepidoptera: Pyralidae) in a Peanut Shelling and Storage Facility[1]

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Abstract The almond moth, *Ephestia* (*Cadra*) *cautella* (Walker) (Lepidoptera: Pyralidae), is an important insect pest in agricultural product processing and storage facilities worldwide, including peanut (*Arachis hypogaea* L.) shelling and storage facilities. We compared the efficacy of nutrient-based solutions as attractants with commercially-available synthetic pheromone traps in controlling almond moth. The treatments were water, 10% honey, 10% beer, and 10% sucrose solutions, pheromone trap in a 3.8-L container, pheromone trap in an empty 3.8-L container, an empty 3.8-L container, and a suspended pheromone trap. The honey solution and pheromone trap in the container trapped the greatest number of moths among the 8 treatments. The pheromone trap in the container trapped significantly more moths than the suspended pheromone trap. We demonstrated that *E. cautella* adults preferred a 10% honey solution over water, 10% beer, or 10% sucrose solutions as attractants. Although the 10% honey solution and the pheromone trap in the container trapped the same number of moths, 70.5% of the moths captured by the honey solution were females and only 21.7% of the moths captured by the pheromone trap in the container were females. A diluted (10%) honey solution could be used in effective and economical traps for *E. cautella* control in storage facilities because it attracts a high percentage of females.

Key Words nutrient solutions, pheromone, *Ephestia cautella, Arachis hypogaea,* stored peanuts

Ephestia spp. (Lepidoptera: Pyralidae) [(e.g., the almond moth, *Ephestia cautella* (Walker), and the Mediterranean flour moth, *E. kuehniella* Zeller] infestations in storage facilities have caused significant economic losses in a variety of stored products (e.g., nuts, grains, fruits, and chocolate) (Phillips 1994, Reichmuth 1999, Ryne et al. 2002). Levels of insect infestations in storage facilities have been monitored using pheromone-baited traps (Ryne et al. 2002). However, mass pheromone trapping yielded limited success as a management strategy for insect pests of stored products (Phillips 1997, Shani and Clearwater 2001). Most pheromone traps are designed to use female-emitted attractive components to attract males, but the high mating ability of the remaining untrapped males of some species may negate any benefits derived

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from the trapping. Traps that attract females or both sexes are essential to effectively reduce pest populations. The use of pheromones in combination with a food odor as attractants for trapping both males and ovipositing females has been investigated for controlling insect pests of stored products (Phillips 1997) and for brownbanded cockroach, *Supella longipalpa* (F.) (Liang et al. 1998). However, improvement in the efficacy of mass adult trapping as a pest management tactic for these insect species remains limited (Phillips 1997, Liang et al. 1998, Ryne et al. 2002).

Insect flight is an energy-expensive activity, and insects use different classes of nutrients as their flight fuels (Boggs 1987). The differences appear to be related to the distance of the flight. Species that do not feed as adults must use stored lipids as flight fuel, whereas species that feed as adults use either carbohydrates or both lipids and carbohydrates. Furthermore, adults flying short-distance feed only on carbohydrate diets, whereas long-distance migrating insects require carbohydrates to support initial short-term flight, then lipids to maintain prolonged migratory flight (Boggs 1987). Thus, nectar feeding could provide nectar sugars for short flight as well as lipids, converted from nectar sugars for long flights (Boggs 1987).

Water is generally scarce in storage facilities, and it has long been considered a limiting factor for the development of insect pests in stored products. Water traps have effectively trapped large numbers of female and male pyralid moths (Chow et al. 1977), in particular *E. cautella* females (Ryne et al. 2002). A comparative study of pheromone and water traps by Ryne et al. (2002) demonstrated that a pheromone dispenser (Agrisense, EP 100A) was effective in trapping *E. kuehniella* males, but not *E. cautella* males. In contrast, water traps were effective for both sexes of *E. cautella*, but not effective in trapping either sex of *E. kuehniella* (Ryne et al. 2002). These results are consistent with *E. kuehniella* being tolerant of dry food sources, whereas *E. cautella* is not (Norris 1934, Benson 1973). Providing water during its adult stage can result in a 60% increase in longevity and fecundity of *E. cautella* (Norris 1934). These earlier studies indicated that water was more effective than pheromone for trapping *E. cautella* moths.

Stored product pests, like *E. cautella*, only fly for a short distance within a storage facility. It is possible that these insects require only carbohydrates to support their flight and reproductive activities. However, *E. cautella* adults have been described as nonfeeding moths with functional mouthparts that are only used to "drink fluids" (Norris 1934, Benson 1973, Ryne et al. 2004). However, if the fluids are nutrient solutions, the insects are feeding when they drink. Although Ryne et al. (2002, 2004) have demonstrated that water traps could be effective in trapping *E. cautella* females, it remains unclear whether nutrient solutions are effective in attracting these moths. Such information could be important in designing improved traps for the control of *E. cautella* in storage facilities.

The objective of this study was to assess the effectiveness of using the nutrient solutions to trap both sexes of *E. cautella* in a peanut (*Arachis hypogaea* L.) storage facility. The nutrient solutions compared included sucrose, diluted honey and beer solutions, and water. An empty container and a commercial pheromone trap were used as negative and positive controls, respectively.

Materials and Methods

Facility location. A peanut storage facility at the USDA-ARS, Crop Genetics and Breeding Research Unit in Tifton, GA, was used to conduct this experiment. It is located at latitude 31.5 N and longitude 83.5 W in a subtropical climate. The experiment was conducted during a 4-wk period of time between 21 July and 17 August 2004. The facility was maintained at 30 ± 5°C and 60-70% RH with natural daylight through the windows; artificial lighting for the room was not used during the period of experiment. The total area of the storage facility used for the experiment was approximately 30 m^2.

Insects. Peanuts in the storage facility were naturally infested with a high level of *E. cautella*. Coleopteran insect pests [e.g., sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae), and flour beetle, *Tribolium* spp. (Coleoptera: Tenebrionidae)] also were identified in the facility, but their populations were much lower than the almond moth population. All insect pests from the traps were identified according to Delinger and Davis (1982) and confirmed by A. N. Sparks, Jr., and S. L. Brown (Department of Entomology, University of Georgia, Tifton, GA). Voucher specimens were deposited at the University of Georgia's Collection of Arthropods, Athens, GA.

Treatment components. Eight treatments in the study were water, 10% (w/v) sucrose water, 10% (w/v) honey, 10% (w/v) beer, a suspended pheromone trap, a pheromone trap in a 3.8-L container, a pheromone trap in an empty 3.8-L container, and an empty 3.8-L container. Sucrose (Fisher Scientific, St. Louis, MO), Great Value™ clover honey (Wal-mart, Inc., Bentonville, AR), Natural Light® beer (Anheuser-Busch, Inc., St. Louis, MO), a pheromone trap (Xlure-R.T.U., Russell IPM, Deeside, UK), and tap water were used in the eight treatments. The commercial pheromone trap was a sticky trap in a diamond shape designed to trap *Plodia* and *Ephestia* moths.

Trap design. Traps were made using 3.8-L white containers (Berry Plastics, Evansville, IN). The containers were lined with two 2-cm wide strips of double-sided sticky tape (Scotch®, 3M, St. Paul, MN) on the upper edge to trap moths. The nutrient-based treatments contained 0.3 L of fluid in 3.8-L white containers, except 0.2 L of solution was used in the first replication of the experiment. The sucrose, honey, and beer solutions were 10% (w/v).

Experimental design. The treatments were arranged in a randomized complete block design. The test was replicated over time with 4 replicates over a 4-wk period of time. The duration of each replication was 6 d with the exception of the first one that was 7 d in duration. All treatments were randomly placed or suspended 2-3 m above the floor in the storage room to minimize any trap location effect.

Data collection and analysis. The total number of moths captured was recorded, and moths were dissected to determine sex (Chapman 1982). Data collected from the four replications in time were analyzed using the PROC GLM procedure of the SAS statistical software version 6.01 (SAS Institute 2000). The means were separated using Ryan-Einot-Gabriel-Welsch multiple range test (α = 0.05) (abbreviated as REGWQ in the SAS software), which is also known as the Ryan's Q test.

Results and Discussion

Because the number of trapped moths was not significantly different among the four replications [i.e., the total number of moths (F = 0.40; df = 3, 31; P = 0.7575), males (F = 1.42; df = 3, 31; P = 0.2582), and females (F = 0.13; df = 3, 31; P = 0.9409)], the data from the four replicates (blocks) were pooled for comparisons. The pooled data showed that the total number of moths (F = 5.54; df = 7, 31; P = 0.0007), males ($F = 5.87$; df = 7, 31; $P = 0.0005$), and females ($F = 6.38$; df = 7, 31; $P = 0.0003$) differed significantly among the eight treatments.

The number of moths trapped by the 10% honey solution and the pheromone trap in the container was significantly higher than either the negative (i.e., empty container) or the positive (i.e., suspended pheromone trap) control (Fig. 1). The data demonstrated that the honey solution was more effective in trapping moths than the suspended pheromone trap. The possibility of adults feeding on nutrient solution was apparent, which however, contradicted the report by Norris (1934) that *E. cautella* does not feed as an adult, although the moths have been described to have functional mouthparts to "drink fluid." Furthermore, when the pheromone trap was suspended in a container filled with 0.3 L water, the combination significantly increased the number of trapped moths in comparison with either only the 0.3-L water container or the suspended pheromone trap. This corroborates the finding of Ryne et al. (2002) who reported that water attracts *Ephestia* spp. In contrast, both the empty containers and the placement of the pheromone traps in empty containers had no effect on moth

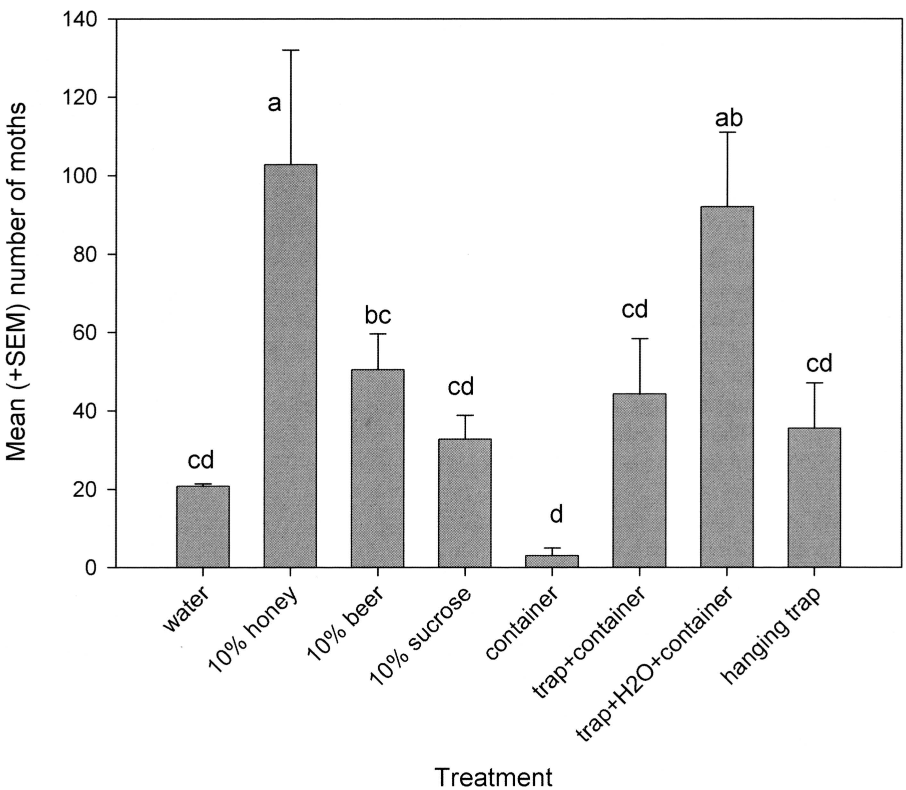

Fig. 1. Effect of the eight treatments on number (Mean ±SEM) of the almond moths captured. The bars with different letters are significantly different ($P < 0.05$, Ryan's Q test). The error bars denote the standard errors of the means (SEM). Results of statistical analysis presented in the text.

trapping (Fig. 1), suggesting that the containers did not influence the results of the experiment. The combination of water and pheromone trap significantly increased the number of moths trapped with only water (Fig. 1). The suspended pheromone trap, water, 10% beer, and 10% sucrose solutions trapped similar number of moths, indicating that the water-based nutrient solutions are important factors in improving the effectiveness of *E. cautella* control in the storage facilities.

When the percentage of the captured females was compared among the treatments, a significant difference ($F = 14.49$; df = 7, 23; $P = 0.0001$) was detected in the percentage of females captured during the study period. The water and nutrient solutions effectively attracted a high percentage of females (Fig. 2). In contrast, the high percentage of males was captured in all treatments with the commercial pheromone traps (i.e., pheromone trap in a container, pheromone trap suspended in a container with water, and pheromone trap suspended from the ceiling) (Fig. 2). The results indicated that the nutrient solutions could be used to effectively trap females to reduce *E. cautella* populations in shelling and storage facilities.

Whereas the pheromone traps have been designed to attract mainly males, the honey solution trapped both sexes. Also, the number of males trapped (31 or 29.5%) by the honey solution was equivalent to the males (35 or 98%) trapped by the sus-

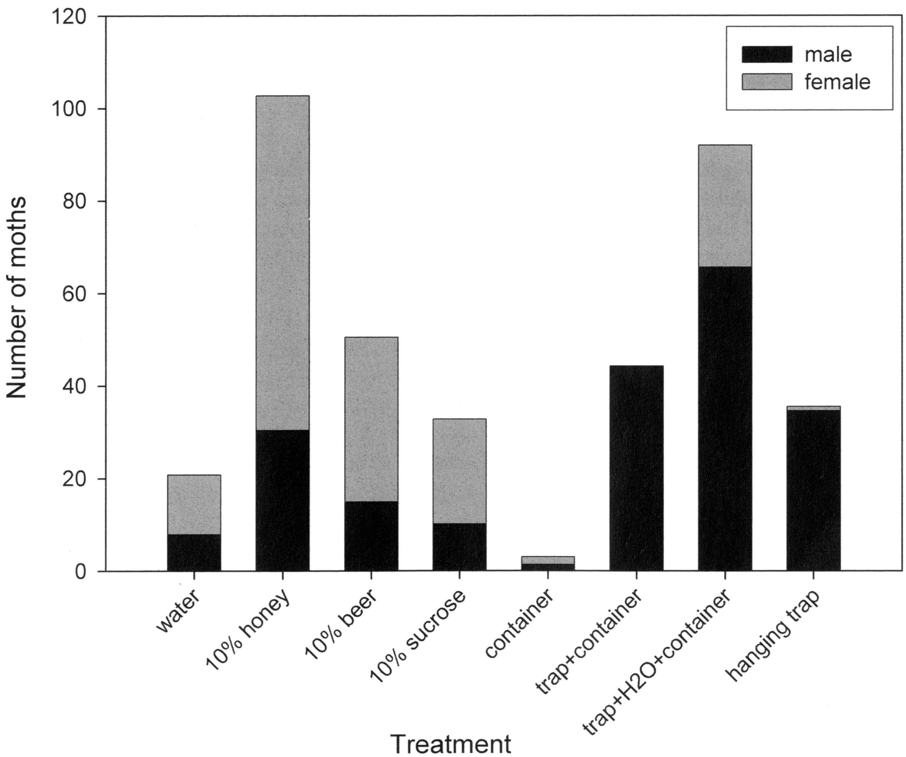

Fig. 2. Influence of the eight treatments on sex composition of the almond moths captured. Results of the statistical analysis presented in the text.

pended pheromone trap (Fig. 2). The honey solution was more effective than the commercial pheromone trap alone. This could be the result of *E. cautella* females being short-distance fliers requiring nutrients for energy supply of their flights (Boggs 1987). Nutrient solutions attracted mainly females, which supported the previous conclusion that the functional mouthparts of *E. cautella* could be used to "drink fluids" and at the same time disproved the previous conclusion that *E. cautella* does not feed as an adult (Norris 1934, Benson 1973, Ryne et al. 2004). The findings also clarified that the previously described "fluid drinking" could actually be feeding of *E. cautella* on nutrient solutions. Furthermore, the high percentage of females captured by the nutrient solutions also could be the result of required-feeding of the females for their oogenesis in adult stage. Alternatively, another possibility would be that the females could be responding to stimuli in the nutrient solutions that represent oviposition substrates. All possibilities need to be further examined; such information would be valuable in developing new traps for *Ephestia* spp.

Whereas honey and beer solutions were effective in trapping the female moths, the growth of *Aspergillus niger* van Tieghem in the nutrient solutions in 6 d at 30°C could be problematic. Thus, frequently changing of the traps (e.g., possibly every 3 d) would be necessary to avoid mold growth in the traps. Alternatively, the addition of antimicrobial agents [e.g., 1 μM of amphotericin B or itraconazole, diluted antifreeze solution, and/or 15% glycerol to lower water activity (a_w)] could be useful to suppress mold growth (Ni and Streett 2005) in the nutrient solutions. Although we did not examine specifically for the number of moths escaped from the trap, the possibility existed. The addition of a low concentration of an insecticide (e.g., cypermethrin) in the nutrient solution could possibly prevent moth escape, and further improve the trapping efficiency.

Significant improvements in trapping female moths by adding 10% honey suggests that nutrient solutions may have the potential to effectively reduce *Ephestia* populations in storage facilities. The capture of high percentage of females might also be the result of "domino effects" and/or cumulative effects of a small but effective amount of the pheromones (and/or other semiochemicals) emitted by the individuals that had been trapped in the nutrient solutions (Ryne et al. 2002). The nutrient solutions have the potential to be readily used for moth population reduction in a storage facility because they attracted greater numbers of females than males (7:3), which would significantly reduce the offspring population. Based on these results, we postulate that the combination of 10% honey solution with a standard pheromone trap in the 3.8-L container has the potential to effectively reduce *E. cautella* population in all sizes of stored product facilities by placing the number of the modified traps accordingly.

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References Cited

Benson, J. F. 1973. The biology of Lepidoptera infesting stored products, with special reference to population dynamics. Biol. Rev. Camb. Philos. Soc. 48: 1-26.

Boggs, C. L. 1987. Ecology of nectar and pollen feeding in Lepidoptera, Pp. 369-391. *In* F. Slansky, Jr., and J. G. Rodriguez (eds.), Nutritional ecology of insects, mites, spiders, and related invertebrates. John Wiley and Sons, Inc., New York.

Chapman, R. F. 1982. The insects: structure and function. Harvard Univ. Press, Cambridge, MA. 919 p.

Chow, Y. S., D. F. Yen and S. H. Lin. 1977. Water, a powerful attractant for the gravid females of *Plodia interpunctella* and *Cadra cautella.* Experientia 15: 453-455.

Delinger, L. M. and R. Davis. 1982. Insect control in postharvest peanuts, Pp. 521-570. *In* H. E. Pattee and C. T. Young (eds.), Peanut science and technology, American Peanut Research and Education Soc., Yoakum, TX.

Liang, D., A. Zhang, R. J. Kopanic, W. L. Roelofs and C. Schal. 1998. Field and laboratory evaluation of female sex pheromeones for detection, monitoring, and management of brown-banded cockroaches (Dictyoptera: Blattellidae). J. Econ. Entomol. 91: 480-485.

Ni, X. and D. A. Streett. 2005. Modulation of water activity on fungicide effect on *Aspergillus niger* growth in Sabouraud dextrose agar medium. Lett. Appl. Microbiol. 41: 428-433.

Norris, M. J. 1934. Contributions towards the study of insect fertility-III. Adult nutrition, fecundity, and longevity in the genus *Ephestia* (Lepidoptera: Phycitidae). Proc. Zool. Soc. London, pp. 333-360.

Phillips, T. W. 1994. Pheromones of stored-product insects: current status and future perspectives, Pp. 479-486. *In* E. Highly, E. J. Write, H. J. Banks and B. R. Champ (eds.), Proc. Sixth Intern. Working Conf. Stored-Product Prot., Vol. 1, CAB International, Wallingford, U.K.

1997. Semiochemicals of stored-product insects: research and applications. J. Stored Prod. Res. 33: 17-30.

Reichmuth, C. O. 1999. Trends in stored-product protection—the German perspective. Phytoparasitica 27: 3-7.

Ryne, C., M. Ekeberg, P.-O. C. Olsson, P. G. Valeur and C. Löfstedt. 2002. Water revisited: a powerful attractant for certain stored-product moths. Entomol. Exp. Appl. 103: 99-103.

Ryne, C., P. A. Nilsson and M. T. Siva-Jothy. 2004. Dietary glycerol and adult access to water: effects on fecundity and longevity in the almond moth. J. Insect Physiol. 50: 429-434.

SAS Institute. 2000. The SAS system for Windows computer program, version 8.01. Cary, NC.

Shani, A. and J. Clearwater. 2001. Evasion of mating disruption in *Ephestia cautella* (Walker) by increased pheromone production relative to that of undisrupted populations. J. Stored Prod. Res. 37: 237-252.