Journal of Chemical Ecology, Vol. 16, No. 8, 1990

SAMPLING RANGE OF MALE SWEETPOTATO WEEVILS (*Cylas formicarius elegantulus*) (SUMMERS) (COLEOPTERA: CURCULIONIDAE) TO PHEROMONE TRAPS: INFLUENCE OF PHEROMONE DOSAGE AND LURE AGE

L.J. MASON,[1] R.K. JANSSON,[1] and R.R. HEATH[2]

[1]*University of Florida*
Institute of Food and Agricultural Sciences
Tropical Research and Education Center
18905 S.W. 280 Street
Homestead, Florida 33031

[2]*U.S.D.A., A.R.S.*
Insect Attractants, Behavior and Basic Biology Research Laboratory
Gainesville, Florida 32604

(Received October 6, 1989; accepted February 26, 1990)

Abstract—Studies were conducted to determine the effects of sex pheromone dosage and lure age on movement of male sweetpotato weevils (SPW), *Cylas formicarius elegantulus* (Summers), using mark-release-recapture techniques. SPW trap counts from various downwind distances were compared for dosages ranging from 0.01 to 10.0 μg and lure ages ranging from fresh (0 days old) to 64 days old. The percentages of male SPW recaptured decreased with an increase in release distance and decreased with a decrease in dosage at each corresponding distance. Most SPW were caught within the first 16-hr period. Slopes of percent recapture vs. release distance for the two higher dosages (10 μg and 1.0 μg) differed from those of the two lower dosages (0.1 and 0.01 μg) but did not differ from each other. Intercepts were similar among the three higher dosages. Slopes did not differ among the five lure ages examined. Intercepts differed between fresh (0 days old) and 24-day-old septa at 16 hr and between fresh (0 days old) and 34-day-old septa at 40 hr. Previous exposure to pheromone (conditioning) did not increase percentages of SPW recaptured. Results indicate that male SPW are capable of traversing distances of at least 280 m in 16 hr. The pheromone tested in this study appears to be effective at dosages lower than any other coleopteran sex-pheromone system. Incorporation of this pheromone into a SPW management system may effectively reduce the use of insecticides.

0098-0331/90/0800-2493$06.00/0 © 1990 Plenum Publishing Corporation

Key Words—*Cylas formicarius elegantulus* (Summers), Coleoptera, Curculionidae, sex pheromone, sweetpotato weevil, mark–release–recapture.

INTRODUCTION

Mechanisms and rates of dispersal for *Cylas formicarius elegantulus* (Summers), the sweetpotato weevil (SPW), have been mostly speculative. Initially, SPWs were thought to fly only the short distances from infested sweet potato plantings to noninfested neighboring plants (Cockerham et al., 1954). Early mark–release–recapture studies in Louisiana indicated that SPW may be able to move distances of up to 2 km. However, since SPW released on individual dates were not marked differently, the time required to traverse this distance could not be determined (Deen, 1940; Cockerham et al., 1954).

Coffelt et al. (1978) recognized that a female SPW produced a sex pheromone that attracted only males. In subsequent laboratory studies, the active component of the pheromone was isolated, identified, synthesized, and bioassayed (Heath et al., 1986). Field trials in the U.S. Virgin Islands and Florida indicated that trap counts were positively correlated with pheromone dosage and that males could travel 70 m in 24 hr from the nearest source of weevils to a pheromone trap baited with 10 μg of synthetic sex pheromone (Proshold et al., 1986; Jansson et al., 1990). These studies indicated that this pheromone was attractive at low dosages. However, the range of attraction and sampling range for the pheromone was not determined.

Wall and Perry (1987) suggested that it is only through carefully timed mark–release–recapture experiments that reasonable evidence concerning the range of pheromone attraction can be acquired. The objective of this study was to examine the movement of male SPW to pheromone traps baited with different dosages of synthetic pheromone and lure ages by utilizing timed mark–release–recapture techniques. Through these studies we hoped to determine the sampling range of the pheromone for SPW.

METHODS AND MATERIALS

SPW males that had been trapped in commercial sweet potato [*Ipomoea batatas* (L.) Lam.] fields were held in the laboratory for one week. Males were then painted on the thorax with different colors of enamel paint, and released at various distances downwind from the pheromone source. The trap used in all experiments was a plastic funnel trap (Jansson et al., 1989). This trap was shown to be the most effective trap for male SPW in southern Florida (Jansson et al., 1989; Jansson and Heath, 1990; Jansson et al., unpublished data). Synthetic sex-pheromone [(*Z*)-3-dodecen-1-ol-(*E*)-2-butenoate) (99.9% pure) that

had been synthesized at the U.S.D.A., A.R.S., Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida, was applied to methylene chloride-extracted rubber septa (Thomas Scientific, Swedesboro, New Jersey) as previously described (Heath et al., 1986).

Experiments were conducted during the months of July–October in fallow tomato, bean, and squash fields with no prior history of sweet potato planting. These fields were chosen because of their isolation from sweet potato fields that might harbor pheromone-producing, wild SPW females, lack of turbulence-producing obstructions, and lack of interference from nonmarked wild SPW males. Nighttime minimum temperatures ranged from 20°C to 24°C, daytime maximum temperatures ranged from 28°C to 33°C; winds were generally from the east–southeast.

Previous Exposure. To determine if prior exposure to pheromone may have conditioned males to the synthetic pheromone, laboratory-reared males (ages ranging from one to three weeks) with no prior exposure to synthetic pheromone were compared to pheromone-trap-collected males from commercial fields. One hundred males of each type were released simultaneously at distances of 25, 50, 75, and 100 m downwind from a pheromone source late in the afternoon (1630 hr EST). Three plastic funnel traps baited with 10 μg of synthetic pheromone were placed 12.5 m apart in a line perpendicular to the line of weevil release and the prevailing wind direction. Percentages recaptured were determined after 16 and 40 hr. The experiment was replicated five times.

Pheromone Dosage. The influence of pheromone dosage on the percentage of marked males recaptured was determined in the field. Rubber septa loaded with either 0.01, 0.1, 1.0, or 10.0 μg of synthetic pheromone were examined. Three plastic funnel traps baited with the same dosage of pheromone were used per release night. The three pheromone-baited traps were placed 12.5 m apart in a line perpendicular to the line of weevil release and the prevailing wind direction. Marked males (200 males/release distance) were released late in the afternoon (1630 hr EST) downwind from the pheromone traps. Release distances used were 3, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 100, 120, 160, 200, 240, and 280 m, with up to seven release distances examined per night. The number of distances examined each night was limited by the number of paint colors available and the number of male weevils available for release. Each distance was tested at least twice. The number of males recaptured in the three traps were totaled 16 hr after male release. The males recaptured between 16 and 40 hr were recorded and added to the 16-hr total. Thus the 40-hr catch represents a cumulative total.

Lure Age. To determine if lure age influenced male response to pheromone, rubber septa loaded with 10 μg of synthetic sex pheromone were aged outdoors for either 0, 14, 24, 34 or 64 days. Each lure age was replicated four times. Experimental design was similar to that previously described, except that

only 100 male SPW were released at each distance and the distances tested were 25, 50, 75, and 100 m.

Data were analyzed by regressing arcsin transformed percentages of weevils recaptured on release distance for each male type (conditioned or nonconditioned), pheromone dosage, and lure age. Parameter estimates were compared between male types, among dosages and among lure ages within time periods, and between time periods within dosages and lure ages using the general linear test (Neter and Wasserman, 1974).

RESULTS

Previous Exposure. Laboratory-reared and pheromone-trap-collected males did not differ in their percent recapture to synthetic sex pheromone when released from various distances downwind of traps (16-hr slopes: $P = 0.4346$, $F_{1,52} = 0.62$; intercepts: $P = 0.6322$, $F_{1,52} = 0.23$; 40-hr slopes: $P = 0.4551$, $F_{1,52} = 0.57$; intercepts: $P = 0.6542$, $F_{1,52} = 0.20$). Thus, prior experience with the synthetic pheromone did not influence the percentage of male SPW recaptured.

Pheromone Dosage. Pheromone dosage significantly influenced percentage recapture of marked male SPW released at different distances downwind from the pheromone source. Percentages of SPW males recaptured decreased with an increase in release distance and decreased with a decrease in dosage at each corresponding distance (Figure 1). At distances of 280 m, percentage recaptured averaged ca. 10% at a dosage of 10 μg. For the 0.01-, 0.1-, and 1.0-μg dosages a 10% level of recapture was found at ca. 5, 70, and 120 m, respectively. The regression parameter estimates are given in Table 1. In general, slopes did not differ between 10- and 1-μg dosages at 16 and 40 hr, but the slopes of these two dosages differed from those of 0.10 and 0.01 μg at 16 hr and from that of 0.01 μg at 40 hr. Intercepts did not differ ($P > 0.05$) among the three higher dosages (10.0, 1.0, and 0.10 μg), but intercepts for these three dosages were significantly greater ($P < 0.05$) than that for the lowest dosage (0.01 μg) at both 16 and 40 hr. Release rate of the pheromone from rubber septa increases with an increase in dosage (Heath et al., 1990). Thus, it is doubtful that similar recapture rates for these three dosages (10.0, 1.0, and 0.10 μg) are due to similar release rates in the field. It is more likely that behavioral saturation to the pheromone is occurring. Most SPW were caught within the first 16 hr. This is similar to observations by Proshold et al. (1986), who found more SPW males were caught during the first night that pheromone traps were placed in sweet potato fields on the U.S. Virgin Islands. Parameter estimates were similar ($P > 0.05$) between the 16- and 40-hr catch for most dosages (Table 1). Only the intercept of the lowest dosage differed ($P < 0.05$) between time periods.

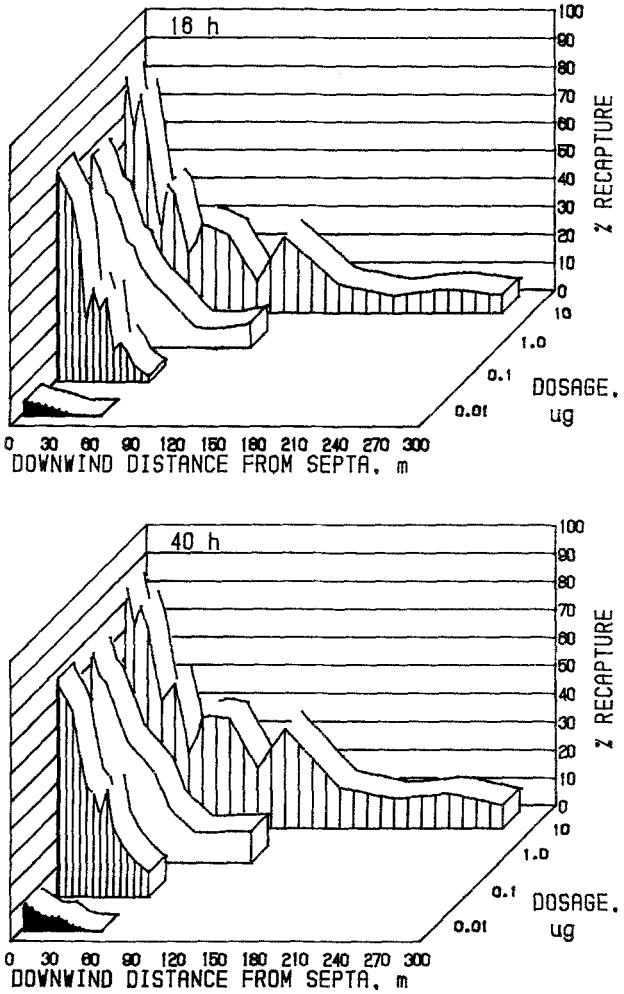

FIG. 1. Percentages of marked SPW males recaptured at 16 and 40 hr in plastic funnel traps baited with different dosages of synthetic sex pheromone when released at different distances downwind of the pheromone source.

These results indicate that male SPW are capable of traversing distances of up to 280 m in less than 16 hr. This is probably accomplished by very short trivial flights (Mason et al., unpublished data). When males were placed at each release site, they typically climbed to the top of the nearest vegetation and flew toward the trap within minutes after their release. The distances of these flights were generally 1–2 m.

TABLE 1. REGRESSION PARAMETER ESTIMATES FOR INFLUENCE OF SPW RELEASE DISTANCE ON PERCENTAGES RECAPTURED FOR EACH OF FOUR PHEROMONE DOSAGES AND TWO SAMPLING PERIODS

Dosage (μg)	Intercept (SE)	Slope (SE)	F	df	P	r^2
16 hr						
0.01	0.09 (0.007)a,A[a]	−0.051 (0.005)a,A	76.70	1,14	0.0001	0.84
0.10	1.35 (0.107)b,A	−0.702 (0.076)b,A	85.39	1,24	0.0001	0.78
1.00	1.13 (0.064)b,A	−0.512 (0.042)c,A	146.71	1,24	0.0001	0.85
10.00	1.27 (0.079)b,A	−0.518 (0.045)c,A	129.25	1,32	0.0001	0.80
40 hr						
0.01	0.14 (0.015)a,B	−0.073 (0.011)a,A	38.24	1,14	0.0001	0.73
0.10	1.32 (0.111)b,A	−0.629 (0.082)b,A	58.88	1,20	0.0001	0.74
1.00	1.23 (0.066)b,A	−0.540 (0.044)b,A	150.22	1,20	0.0001	0.86
10.00	1.35 (0.070)b,A	−0.522 (0.040)b,A	167.36	1,20	0.0001	0.83

[a] Parameter estimates followed by different lowercase letters within the same sampling period indicate significant differences among dosages, and estimates followed by different uppercase letters within the same dosage indicate significant differences between sampling periods [$P < 0.05$ general linear test (Neter and Wasserman, 1974)].

Lure Age. Percentages of marked SPW males recaptured were negatively correlated with release distance for each lure age. There were no significant differences between the slopes for the five lure ages examined according to a test for homogeneity of slopes ($P > 0.05$) (Table 2 and Figure 2). However, intercepts did differ among ages (Table 2). Intercepts differed between fresh lures (0 days old) and 24- and 64-day-old lures at 16 hr, but not at 40 hr. Intercepts for fresh lures did not differ from those of 14- and 34-day-old lures at 16 hr, and from those of 14-, 24-, and 64-day-old lures at 40 hr. The few differences found probably were due, in part, to environmental conditions. Lower percentages of males were recaptured during cooler and/or rainy weather. This indicates that environmental factors such as nighttime temperature and precipitation can influence male movement to pheromone traps (Mason et al. unpublished data). Currently, we are determining the influence of environmental factors such as temperature, precipitation, wind speed and direction, and biological factors, such as male age and reproductive status, on male movement to pheromone-baited traps. These data show that the attractiveness of synthetic pheromone formulated on methylene-chloride-extracted rubber septa to male SPW did not decrease for lure ages between 0 and 64 days old. Jansson et al. (1990) found that attractiveness of pheromone formulated on rubber septa did not decrease appreciably for lures between 0 and 34 days old.

TABLE 2. REGRESSION PARAMETER ESTIMATES FOR INFLUENCE OF SPW RELEASE DISTANCE ON PERCENTAGES RECAPTURED FOR EACH OF FIVE LURE AGES AND TWO SAMPLING PERIODS

Lure age (days)	Intercept (SE)	Slope (SE)	F	df	P	r^2
16 hr						
0	1.07 (0.16)a[a]	−0.47 (0.09)a	22.48	1,22	0.0001	0.51
14	1.28 (0.20)ab	−0.62 (0.12)a	24.41	1,22	0.0001	0.53
24	0.85 (0.11)b	−0.43 (0.07)a	43.33	1,22	0.0001	0.66
34	1.94 (0.09)ab	−0.47 (0.06)a	59.55	1,22	0.0001	0.73
64	0.87 (0.12)b	−0.45 (0.07)a	36.66	1,22	0.0001	0.63
40 hr						
0	0.98 (0.20)a	−0.40 (0.12)a	10.54	1,22	0.0001	0.32
14	1.39 (0.21)ab	−0.64 (0.13)a	23.53	1,22	0.0001	0.52
24	0.96 (0.13)ab	−0.47 (0.08)a	36.80	1,22	0.0001	0.63
34	0.65 (0.17)b	−0.30 (0.11)a	8.33	1,22	0.0001	0.28
64	1.15 (0.11)ab	−0.57 (0.07)a	63.67	1,22	0.0001	0.74

[a] Parameter estimates followed by different lowercase letters within the same sampling period indicate significant differences among dosages [$P < 0.05$ general linear test (Neter and Wasserman, 1974)].

DISCUSSION

Mark–release–recapture studies on long-range movement of insects to attractant sources are scarce. Wall and Perry (1987), in summarzing the literature for lepidopteran insects, found that many studies claiming to demonstrate the range of attraction (maximum distance over which insects show directed movement to a source) actually demonstrated sampling range (maximum distance in which insects are shown to reach a source in a given period of time). Unfortunately, the time required for insects to traverse this distance, even in sampling-range studies, is often neglected or broadly defined. Mark–release–recapture studies that are carefully timed, give the form and concentration of the attractant used, habitat information, and environmental conditions under which the experiment was conducted (all of which can influence pheromone dispersal and insect movement) are the most informative (Wall and Perry, 1987). While most work has concentrated on lepidopterans, especially noctuids, few studies have been published on coleopterans. Work on coleopterans has focused on bark beetles and the boll weevil (*Anthonomus grandis* Boheman), probably due to the devastating damage done by these insects, the ability of chemists to isolate an attractant and characterize it, and entomologists' ability to document

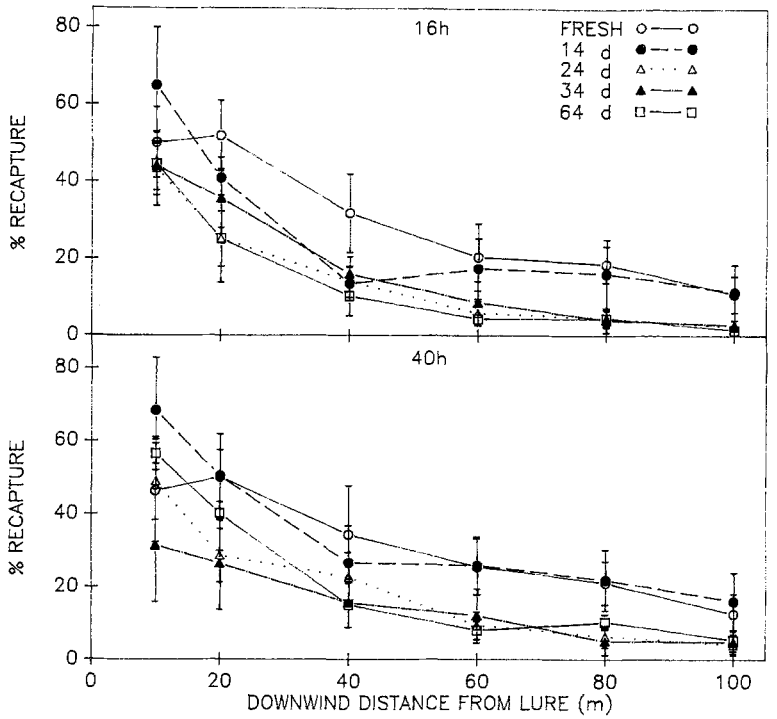

FIG. 2. Percentages of marked SPW males recaptured in plastic funnel traps baited with 10-μg lures of different ages when released at different distances downwind.

its efficacy in the field. In the current study we were able to determine that the sampling range for SPW is at least 280 m when a pheromone source of 10 μg is used as an attractant. Current behavioral work is underway to determine the absolute range of attraction for SPW.

Boll weevils are able to disperse great distances. The longest record is 72 km traversed by two weevils. These marked weevils were recovered in grandlure-baited traps 15–16 days (19.4 m/hr) and 29–33 days (9.6 m/hr) later (Johnson et al., 1976). This equaled a record for unmarked boll weevils in Mexico (Davich et al., 1970). Over a shorter time period, a marked male boll weevil traveled 400 m in 2–5 days (8.3–3.3 m/hr), while a marked female traveled 1600 m in 1–4 days (66–16 m/hr). Another female was able to traverse 272 m in 2 days (5.6 m/hr). In comparison, male SPW are able to traverse 280 m in under 16 hr (17.5 m/hr). This is comparable to the fastest rate found for the boll weevil (Johnson et al., 1976). Lepidoptera have very quick mark–release–recapture times (Baker and Roelofs, 1981; Karandinos, 1974; Kehat et al., 1976; Kishaba et al., 1970). Thirty percent of marked cabbage looper, *Trichoplusia*

ni (Hubner), males released 105 m downwind from a 25-mg pheromone source were recovered within 15 min (i.e., 420 m/hr) (Kishaba et al., 1970). At distances of up to 300 m, 6% were recovered in 15 min (1200 m/hr). Lesser peachtree borer males, *Synanthedon pictipes* (Grote and Robinson), have recapture rates of up to 66 m/hr when responding to traps baited with virgin females (Karandinos, 1974).

In laboratory bioassays of various insects, pheromone dosage is typically positively correlated with male response up to some threshold level (Coffelt and Burkholder, 1972; Shorey and Gaston, 1964). Similar trends have been found in the field. The percentages of males recovered in pheromone traps decreases as the downwind release distance increases and dosage decreases (Karandinos, 1974; Proshold et al., 1986). Although we found no differences between the slopes or intercepts for dosages within the range of 1.0–10.0 μg, there was a positive correlation between dosage and percentage recapture of SPW males within the range of 0.01–1.0 μg. The dosages that we tested are considerably lower than those dosages used in other coleopteran trapping studies. For instance, 0.4–25 mg of grandlure was used in boll weevil dose–response tests (Hardee et al., 1974). Schlyter et al. (1987) used dosages in the range of 0.5–500 mg (release rate/day) for 2-methyl-3-buten-2-ol and 0.01–10 mg (release rate/day) for *cis*-verbenol to examine attraction of *Ips typographus* (L.). Thus, compared to other coleopteran systems, SPW males are extremely sensitive to the female pheromone.

Acknowledgments—We thank A. Sweeney, T. Bailey, and S. Glenn for their assistance in painting weevils and data collection; B. Dueben for loading of pheromone; P.L. Phelan and K.F. Haynes for their helpful comments on an earlier version of this manuscript; and the anonymous reviewers for their constructive suggestions. This research was supported, in part, by the U.S. Department of Agriculture under CRSR Special Grants 87-CRSR-2-3107 and 88-34135-3571 (to R.K.J.) managed by the Caribbean Basin Advisory Group (CBAG) and under CRSR Special Grant 88-34103-3262 (to R.K.J.) managed by the Southern Region IPM Program. This is Florida Agricultural Experiment Station No. R00182.

REFERENCES

BAKER, T.C., and ROELOFS, W.L. 1981. Initiation and termination of oriental fruit moth male response to pheromone concentrations in the field. *Environ. Entomol.* 10:211–218.

COCKERHAM, K.L., DEEN, O.T., CHRISTIAN, M.B., and NEWSON, L.D. 1954. The biology of the sweet potato weevil. *La. Tech. Bull.* 483. 30 pp.

COFFELT, J.A., and BURKHOLDER, W.E. 1972. Reproductive biology of the cigarette beetle, *Lasioderma serricorne*. 1. Quantitative laboratory bioassay of the female sex pheromone from females of different ages. *Ann. Entomol. Soc. Am.* 65:447–450.

COFFELT, J.A., VICK, K.W., SOWER, L.L., and MCCLELLAN, W.T. 1978. Sex pheromone of the sweetpotato weevil, *Cylas formicarius elegantulus*: Laboratory bioassay and evidence for a multicomponent system. *Environ. Entomol.* 7:756–758.

DAVICH, T.B., HARDEE, D.D., and JESUS ALCALA, M. 1970. Long-range dispersal of boll weevils determined with wing traps baited with males. *J. Econ. Entomol.* 63:1706–1708.

DEEN, O.T. 1940. Observations on flight of the sweetpotato weevil. *La. Agric. Exp. Stn. Bull.* 323:40–41.

HARDEE, D.D., MCKIBBEN, G.H., RUMMEL, D.R., HUDDLESTON, P.M., and COPPEDGE, J.R. 1974. Response of boll weevils to component ratios and doses of the pheromone, grandlure. *Environ. Entomol.* 3:135–138.

HEATH, R.R., COFFELT, J.A., SONNETT, P.E., PROSHOLD, F.I., DUEBEN, B., and TUMLINSON, J.H. 1986. Identification of sex pheromone produced by female sweetpotato weevil, *Cylas formicarius elegatulus* (Summers). *J. Chem. Ecol.* 12:1489–1503.

HEATH, R.R., COFFELT, J.A., PROSHOLD, F.I., JANSSON, R.K., and SONNETT, P.E. 1990. Sex pheromone of sweetpotato weevil: History and implications of chemistry in weevil management, *in* R.K. Jansson and K.V. Raman (eds.). Sweet Potato Pest Management: A Global Perspective. Westview, Boulder, Colorado. In press.

JANSSON, R.K., and HEATH, R.R. 1990. Development of a sex pheromone monitoring system for sweetpotato weevil management, pp. 543–552, *in* R. Howeler (ed.). Proceedings 8th Symposium of the International Society for Tropical Root Crops. CIAT, Bangkok, Thailand. 712 pp.

JANSSON, R.K., HEATH, R.R., and COFFELT, J.A. 1989. Temporal and spatial patterns of sweetpotato weevil (Coleoptera: Curculionidae) counts in pheromone-baited traps in white-fleshed sweet potato fields in southern Florida. *Environ. Entomol.* 18:691–697.

JANSSON, R.K., PROSHOLD, F.I., MASON, L.J., HEATH, R.R., and LECRONE, S.H. 1990. Monitoring sweetpotato weevil (Coleoptera: Curculionidae) with sex pheromone: Effects of dosage and age of septa. *Trop. Pest Manage.* In press.

JOHNSON, W.L., CROSS, W.H., and MCGOVERN, W.L. 1976. Long-range dispersal of marked boll weevils in Mississippi during 1974. *Ann. Entomol. Soc. Am.* 69:421–422.

KARANDINOS, M.G. 1974. Recovery of *Synanthedon pictipes* males released at various distances downwind of sex pheromone traps. *Environ. Entomol.* 3:932–925.

KEHAT, M., NAVON, A., and GREENBERG, S. 1976. Capture of marked *Spodoptera littoralis* (Boisd). male moths in virgin female traps: Effects of wild male population, distance of traps from release point, and wind. *Phytoparasitica* 4:77–83.

KISHABA, A.N., TOBA, H.H., WOLF, W.W., and VIAL, P.V. 1970. Response of laboratory-reared male cabbage looper to synthetic sex pheromone in the field. *J. Econ. Entomol.* 63:178–181.

NETER, J., and WASSERMAN, W. 1974. Applied Linear Statistical Models, R.D. Irwin, Inc. Homewood, Illinois. 842 pp.

PROSHOLD, F.I., GONZALEZ, J.L., ASENCIO, C., and HEATH, R.R. 1986. A trap for monitoring the sweetpotato weevil (Coleoptera: Curculionidae) using pheromone or live females as bait. *J. Econ. Entomol.* 79:641–647.

SCHLYTER, F., LOFQVIST, J., and BYERS, J.A. 1987. Behavioural sequence in the attraction of the bark beetle *Ips typographus* to pheromone sources. *Physiol. Entomol.* 12:185–196.

SHOREY, H.H., and GASTON, L.K. 1964. Sex pheromone of noctuid moths. III. Inhibition of male response to the sex pheromone in *Trichoplusia ni* (Lepidoptera: Noctuidae). *Ann. Entomol. Soc. Am.* 57:775–779.

WALL, C., and PERRY, J.N. 1987. Range of action of moth sex-attractant sources. *Entomol. Exp. Appl.* 44:5–14.