韓應昆誌 36(3): 270 ~ 276 (1997)
Korean J. Appl. Entomol.

Field Performance of Insecticidal Baits for German Cockroach (Blattaria: Blattellidae) Control

바퀴에 대한 독먹이 제제의 야외 방제 효과

Dong Kyu LEE
이동규

ABSTRACT Bait formulations containing 5.0% micro-capsuled fenitrothion, 2.0% hydramethylnon or 0.8% chlorpyrifos were evaluated in an 8 week field experiment against German cockroach, *Blattella germanica* (L). In German cockroach infested 15 restaurants, micro-capsuled fenitrothion (avg. 82.8%) was more effective at reducing adult German cockroach populations than chlorpyrifos (avg. 68.4%), but was about equally as effective as hydramethylnon (avg. 86.1%). The baits of micro-capsuled fenitrothion (avg. 76.5%), hydramethylnon (avg. 82.8%) and chlorpyrifos (avg. 74.9%) almost equally reduced nymphal German cockroach populations in the field. Most baits remained in the bait stations at the heavily infested restaurants after the 8 week treatments. However, the contents of hydramethylnon baits had been subject to significantly greatest consumption (0.72 g) and the remaining bait was on the average of 57% by German cockroaches. It was assumed that the previous phenomenon of extra consumption of bait was explained by the infesting cockroaches continuously taking these baits because of the mode of action, the bait food material and the population densities of German cockroaches.

KEY WORDS cockroach control, insecticidal bait, field performance, bait consumption

초 록 5.0% micro-capsuled fenitrothion, 2.0% hydramethylnon, 또는 0.8% chlorpyrifos가 주요 활성물질인 독먹이 제제의 방제효과를 알아보기 위하여 바퀴, *Blattella germanica* (L)가 번식하고 있는 15개의 식당에서 8주동안 야외실험을 실시한 결과는 다음과 같다. 바퀴 성충에 대한 방제효과는 micro-capsuled fenitrothion 제제(평균 82.8%)가 chlorpyrifos 제제(평균 68.4%)보다 유의성 있게 높았으나, hydramethylnon 제제(평균 86.1%)와는 거의 같은 효과를 보였다. 또한, 바퀴 자충에 대한 방제효과는 3가지 독먹이 제제가 거의 같은 유효성(평균 74.9 ~ 82.8%)을 나타내었다. 독먹이 소모량을 조사한 결과, 8주 동안에 서식 바퀴에 의한 micro-capsuled fenitrothion 제제의 소모량은 0.11 g으로, 평균 90% 이상 남아 있었으나, hydramethylnon 제제는 바퀴에 의한 소비량(0.72 g)이 현격하게 많아서 잔여량이 평균 57%로 나타났다. 이러한 결과는 hydramethylnon의 살충 기작의 특성, 유인먹이의 재료, 서식 바퀴의 밀도와 관계가 있는 것으로 추정되었다.

검색어 바퀴 방제, 독먹이, 야외실험, 독먹이 소모량

Cockroach control in houses, apartments and many kinds of residential buildings usually relies on an application of residual insecticides in cockroach infested areas. This strategy often includes use of organophosphate, carbamate and pyrethroid insecticides, which are mixed with water and applied with air-compressed sprayers. Other strategies include pyrethrins, applied as aerosol in cracks and crevices, ultra-low volume meth-

Dept. Biology and Institute of Health Sciences, Kosin University, Pusan 606-701 (고신대학교 생물학과 및 보건과학연구소, 부산 606-701)

ods (Bennett and McNeal, 1974), boric acid and silica aerogel dusts, primarily used as supplements to residual sprays (Moore, 1973). These methods were effective in controlling German cockroaches, using residual treatment in field trials (Grayson and Robinson 1976; Shim and Ree, 1982). However, the application of residual spray requires technical skill and is restricted or else prohibited in sensitive areas such as health facilities, restaurants and residential houses. On the other hand, insecticidal baits have become an effective alternative to traditional ways of controlling the German cockroach, *Blattella germanica* (L.), (Rust, 1986; Milio *et al.*, 1986; Wright and Dupree, 1988; Appel, 1990) and are also safe to the environment, the applicator and residents of that area. The insecticides for toxic baits were usually used with fenitrothion, chlorpyrifos, avermectin and hydramethylnon (Appel, 1990; Koehler *et al.*, 1991). For consumers, insecticidal baits contained in child-resistant containers make them safer and easier to use in public buildings and around homes. Field tests of several baits show promise of suppression with precise placement (Milio *et al.*, 1986; Brenner and Pierce, 1991; Smith *et al.*, 1994). Also, the development of new chemicals and bait formulations have made a significant contribution towards the use of insecticidal baits (Ree *et al.*, 1995).

Many different bait products are marketed for control of German cockroaches in Korea. These products consist of 10 to 12 bait stations and come with instructions to apply all the stations at the same time in the kitchen, bathroom, and other locations where residents have seen cockroaches. Effective bait formulations must be palatable and relatively nonrepellent, readily available, and yet toxic in small amounts (Rust and Reierson, 1981; Appel, 1990). Repellency is actually the most important factor affecting insecticidal bait performance against German cockroaches (Reierson and Rust, 1984; Appel, 1990), but factors such as water content and texture of bait formulations may also affect performance. According to Lane and Appel (1996), one important consideration is competition between baits and other food resources. However, little is known of their comparative effectiveness against domestic cockroaches. The purpose of this study was to evaluate the effect of several insecticidal baits on German cockroaches in the field, and also to determine the effects of bait aging on performance.

MATERIALS AND METHODS

Field Performance. The study was conducted during the autumn of 1996 in 15 restaurants in Pusan. The restaurants were comparatively small (17 m^2 ~ 40 m^2) and unsanitary. They had no program for cockroach control. The study began 14 October 1996 with placement of the sticky traps before treatment. Insecticidal bait treatment was applied on 21 October 1996, and the study ended on 19 December 1996 with the collection of the 8 week traps. Sticky traps (Baqui Ora-Ora Touch, Taepyungyang Chemical Co.) were used to monitor cockroach populations. Four traps were placed in the kitchen of each restaurant. The sticky traps were positioned in a rear corner under the sink, on the upper and lower shelves and adjacent to the refrigerator. Traps were left in place for 3 days, then returned to the laboratory for evaluation. Trap catches were evaluated before treatment and every week for 8 weeks after treatment. The adults and nymphs of the cockroaches were separately counted for evaluations, except for 1st instar nymphs, because the population densities of the 1st nymphs were more affected by gravid females. After determination of the cockroach population density, each restaurant was either designated a control group, or they received one of the 3 insecticidal bait treatments: (1) 5.0% micro-capsuled fenitrothion (SMT MC-G); (2) 2.0% hydramethylnon (Combat Gold); and (3) 0.8% chlorpyrifos (Roach Q) (Table 1).

Treatments were allocated to individual restaurants, based on trap catches prior to treatment, so that the initial catch was equivalent among treatments (Appel 1990, 1992). For treatment, the bait stations for each bait formulation were placed in the kitchens of 3 or 4 restaurants, and the setting rate for the number of bait stations was 1.5 bait station/m^2 in the restaurants. The bait stations were placed on the shelves, inside and behind kitchen furniture, above and behind refrigerators,

Table 1. Characteristics of insecticidal bait formulations evaluated against *Blattella germanica*

Brand	Manufacturer	AI[1]	Concent.(g)	Net wt.(%)	Station Type
SMT MC-G	Sumika	Fenitrothion	5.0	1.5	Quadrangular
Combat Gold	Chlorax	Hydramethylnon	2.0	1.5	Circular on square
Roach Q	Bukwang	Chlorpyrifos	0.8	2.9	Square on octagon

[1] active ingredient

in pantries, and in the rear corners under kitchen sinks. For a control group, 4 restaurants were observed, using no insecticidal baits. Cockroaches were collected at the end of every week to figure out their populations, using the same method as the treatment groups.

Bait Consumption. The baits were weighed after use in the field study. For the unused control group, 3 different baits in the bait stations were deposited without vinyl covers in a paper box and exposed to room temperature and 40 ~ 60% RH in a laboratory. The used and unused baits were weighed at the same time after the field efficacy test to ensure the same extent of evaporated water from the used baits. The percentages of bait consumptions were calculated as the differences between pre-treatment and post-treatment of the baits, divided by weights of the pre-treatment. Sixteen to 23 baits were used for each insecticidal bait formulation. Mass loss was assumed to result entirely from bait loss due to 8 weeks of cockroach consumption.

Data Analysis. Counts of cocktoaches were converted to a percentage reduction for each restaurant, because trap count data were not evenly distributed. Also, the mean numbers of collected cockroaches (both nymphs and adults) were compared with those before treatments. The mortality rates were adjusted with the pre-treatment ratios, according to the following formula (Appel, 1990, 1992; Ree *et al.*, 1995):

$$\% \text{ reduction} = \frac{(\text{no. before treatment} - \text{no. after treatment})}{\text{no. before treatment}} \times 100$$

Percentage reduction data were analyzed using a repeated measures analysis of variance (ANOVA). Differences among the means for each treatment were tested for significance using Duncan's multiple range test. All differences cited were significantly different at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Field Performance. The room temperatures of the restaurants were 20°C ~ 27°C during the test period. The initial populations of German cockroaches (nymph, adult and total) are given in Table 2. The average density estimates before treatment were 108.0, 156.0, 69.6 and 20.4 cockroaches per restaurant for micro-capsuled fenitrothion (5.0% AI), hydramethylnon (2.0% AI), chlorpyrifos (0.8% AI) and untreated control, respectively. All population densities were not equivalent among the study groups because of a shortage of study sites with high cockroach populations. Therefore, the untreated control restaurants were chosen from those restaurants with the lowest initial densities of German cockroaches. However, in spite of their comparatively lower density, the untreated control restaurants might be useful in figuring out the trend of cockroach population change. All treatments succeeded in reducing cockroach populations, in contrast to the untreated controls (Table 2).

The average percent reduction rates for the nymphal German cockroaches were not significantly different among the 3 different bait formulations, except for Roach Q at 6 weeks, which showed a significantly lower reduction rate (i.e. 39.2%) than those of the others (i.e. 60.8% reduction at SMT MC-G and 70.4% reduction at Combat G). With the adult population, the reduction rates were not significantly different between SMT MC-G and Combat G, showing 82.8% and 86.1% in average reduction, respectively; whereas Roach Q reduced to average of 68.4% which, was significantly lower than those of former two baits (Table 2). According to Appel (1990), bait formulations containing chlorpyrifos were more toxic, and generally more repellent

Table 2. Mean percentage of reduction of *B. germanica* in infested restaurants after bait treatment

Treatment	n	Precount[1]	Weeks after treatment[2]								
			1	2	3	4	5	6	7	8	AVG.
Nymph											
Control	4	11.2	−95.0b	−216.5b	−57.3b	−63.0b	−164.0b	−433.0c	−792.0b	−1141.7b	−370.3b
SMT MC−G	4	64.8	63.1a	59.2a	87.1a	87.6a	84.0a	70.4a	76.4a	84.4a	76.5a
Combat G	4	117.2	81.1a	79.7a	92.2a	97.0a	92.6a	60.8a	78.3a	80.8a	82.8a
Roach Q	3	52.8	75.1a	84.9a	89.5a	93.7a	72.5a	39.2b	62.5a	81.7a	74.9a
Adult											
Control	4	9.2	2.2b	−78.3c	−63.7b	−17.5b	−14.2b	−261.8c	−239.5c	−165.5c	−104.8c
SMT MC−G	4	43.2	58.5a	65.5ab	81.9a	95.4a	87.6a	85.6a	91.6a	96.0a	82.8a
Combat G	4	38.8	80.0a	83.6a	91.5a	90.3a	91.7a	69.7ab	90.8a	90.8a	86.1a
Roach Q	3	16.8	63.0a	53.7b	78.5a	85.6a	73.5a	55.3b	69.2b	68.5b	68.4b
Total											
Control	4	20.4	−43.6b	−142.5b	−56.4b	−35.1b	−76.4b	−292.5c	−472.6b	−550.3b	−208.7b
SMT MC−G	4	108.0	58.7a	62.3a	85.6a	91.9a	85.6a	80.1a	84.3a	90.0a	79.8a
Combat G	4	156.0	80.0a	82.2a	93.2a	94.7a	92.7a	66.4a	85.8a	86.8a	85.2a
Roach Q	3	69.6	75.8a	76.3a	86.8a	90.7a	82.0a	48.1b	70.9a	73.9a	72.0a

[1] Mean number of cockroaches presents in the n replicate restaurants before bait treatment.
[2] Means in the same stage and a column followed with the same letters were not significantly different ($P > 0.05$; Duncan's multiple range test [SPSS Incorporated 1986]). Negative values indicate population increase.

than hydramethylnon baits. He reported that hydramethylnon baits were the most effective consumer bait formulations for German cockroach control among treatments of boric acid, chlorpyrifos and hydramethylnon. The reduction rates of German cockroach nymphs between SMT MC−G and Combat G was similar with those of adults, while the nymph densities of the untreated control group increased much more dramatically than those of adult densities (ave. 370.3% versus ave. 104.8% increase). With the nymph population, SMT MC−G, Combat G and Roach Q exhibited high suppressions during the 8 week period (>74.9% avg. reduction) (Table 2). In SMT MC−G baits, the total reduction rates of nymph and adult German cockroaches were 62.3%, 91.9%, 80.1% and 90.0% after 2, 4, 6 and 8 weeks, respectively. Combat G gave 82.2% of total reduction rates after 2 weeks, 94.7% after 4 weeks, 66.4% after 6 weeks and 86.8% after 8 weeks. In case of Roach Q, the reduction rates of the population were 76.3% after 2 weeks, 90.7% after 4 weeks, 48.1% after 6 weeks and 73.9% after 8 weeks. The population densities in the untreated control did not decrease, but rather increased to 550.3% after 8 weeks and an average of more than 200% throughout the test period.

In the untreated control, the population of German cockroaches gradually increased, from an average of 20.4 individuals to an average of 115.6 individuals after 8 weeks. Therefore, the actual control effects of all the insecticidal bait formulations should be higher than the results in the reduction rates of nymph and adult populations. In this study, the toxic bait treatments resulted in similar reductions of German cockroach densities between SMT MC−G and Combat G, although they did not control completely. There was no evidence of habitat disruption, which would create unsuitable conditions, thus being an additional factor in population reduction.

Many factors influence the control effect of insecticidal bait treatment against cockroaches. Factors such as food management and sanitary conditions in kitchens, the amount of harborage, and the quantity of bait stations, as well as the active ingredients, repellency and amount of moisture in the baits (Appel, 1992; Lee, 1995; Lee and Jun, 1995). This result of German cockroach reduction through insecticidal baits was somewhat lower than in some other studies, and somewhat higher than in others. MacDonald *et al.*(1987) reported that 1.65% hydramethylnon baits (0.3 ~ 0.6 bait/m^2) brought 100% control of German cockroaches in laboratory animal rooms over a 3 month period. Lee (1995) and Ree *et al.*(1995) suggested that the simpler environ-

mental conditions made it easier to control not only domestic cockroaches but peridoestic cockroaches outside houses. They also suggested that the amount of insecticidal bait in each bait station played an important role for cockroach control. The data of this study suggested that the number of bait stations is one of the most important factors in controlling cockroaches. Use of more bait stations increases not only the amount of insecticide per house, but increases the number of treated locations, thus ensuring better areawide coverage (Appel, 1992). Ogg and Gold (1993) indicated that a 1.65% hydramethlnon bait was evaluated in the ratio of 0.1 bait/m^2 against German cockroaches in apartments, and did not successfully reduce German cockroaches, with reductions of less than 54.4% in 12 weeks. On the other hand, with a ratio of 1.0 bait/m^2, hydramethylnon baits controlled populations better, demonstrating 90.9%, 72.5% and 81.8% reductions when measured at weeks 4, 8 and 12, respectively, of German cockroach densities in the sick rooms of a hospital (Lee, 1993). Also, Reierson *et al.*(1983) and Milio *et al.*(1986) indicated that the increased performance of hydramethylnon can be obtained by using more bait stations in apartments.

Since the introduction of hydramethylnon in 1985, this insecticide has stimulated the development of a number of competitive bait products (Appel, 1990). The hydramethylnon has significantly reduced German cockroach infestations, and it remains effective for more than 3 months (Milio *et al.*, 1986; Wright and Dupree, 1988; Appel, 1990; Lee, 1993). The fenitrothion was recently deveoped into a micro-capsuled chemical. In other field studies, the micro-capsuled fenitrothion baits showed a significantly higher reduction of German cockroach infestations, as compared to chlorpyrifos, for a period of more than 4 months (Lee, 1993, 1994). According to the results of this study, no differences between 5.0% micro-capsuled fenitrothion (i.e. 91.9% and 90.0% reductions after 4 and 8 weeks, respectively) and 2.0% hydramethylnon (i.e. 94.7% and 86.8% reductions after 4 and 8 weeks, respectively) were detected. This was using a ratio of 1.5 bait/m^2 in fighting German cockroaches at restaurants in Pusan.

Bait Consumption. Most baits remained in the bait stations after the 8 week treatments (Fig. 1). The aver-

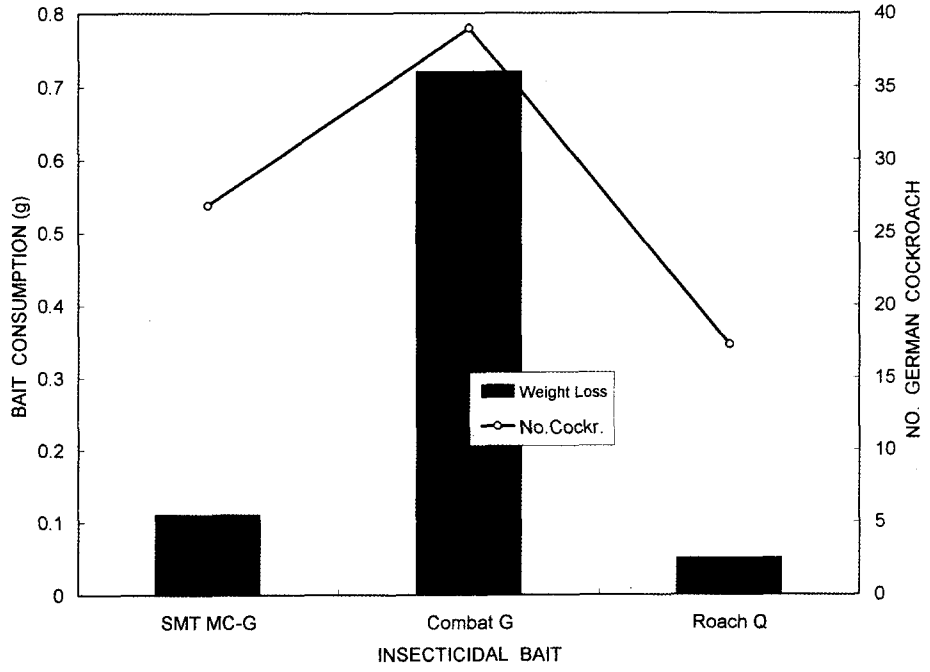

Fig. 1. Consumption of the insecticidal baits and mean numbers of infested German cockroaches per trap at the restaurants before treatment.

ages of 0.11 g in SMT-G, 0.72 g in Combat Gold and 0.05 g in Roach-Q were taken by the infested cockroaches (Fig. 1). The highest and the lowest average weight losses for 8 weeks were Combat G and Roach Q, respectively. That might be due to their mode of actions, the bait food materials and the population densities of German cockroaches.

In one restaurant, the contents of Combat G baits were completely consumed by German cockroaches. It was assumed that the restaurant had the heaviest infestation of German cockroaches at its initial population an avg. of 118.0 individuals per trap. Moreover, the cockroaches might continuously take the baits because of the mode of the active ingredient. Amidinohydrazone hydramethylnon is slower acting than the other insecticides. Lee and Jun (1995) reported that 2.0% hydramethylnon (Combat G) was less effective, reducing 48.5% of the German cockroaches for 2 days, than 5.0% micro-capsuled fenitrothion (ave. 100.0%) and 0.8% chlorpyrifos (Roach Q) (ave. 78.5%) in a laboratory evaluation. Also, Appel (1992) showed a similar result, that LT_{50} of 2.0% hydramethylnon (Maxforce) was 2.40 days against German cockroaches in 0.95-liter jars. Therefore, the cockroaches that had more time to take the baits even after the initial intake will die in about 2 days. On the other hand, fenitrothion and chlorpyrifos act quickly to kill insects. These insecticides kill them within 4 hours after intake (Lee and Jun, 1995). Therefore, cockroaches have not had much time to take the baits again after initial intake. Therefore, the reduction rates of German cockroaches were not directedly correlated with bait consumption rates in the field evaluation. Again, the consumption rates of the insecticidal baits might be related with 1) the population densities of infested cockroaches 2) the insecticides' active ingredients 3) the bait food materials and 4) food management and sanitation in restaurants, since the worse food management and sanitation of the restaurants can give cockroaches more chances to take food rather than toxic baits.

ACKNOWLEDGEMENTS

I thank D.J. Lee, K.S. Jang, Y.S. Jung, Y.B. Ha and Y.S. Yoon for their assistance in laboratory and field works. I also thank T. Okuno and F. Nishioka of Sumika Life-Tech Company for their support.

REFERENCES

Appel, A.G. 1990. Laboratory and field performance of consumer bait products for German cockroach (Dictyoptera: Blattellidae) control. J. Econ. Entomol. **83**: 153-159.

Appel, A.G. 1992. Performance of gel and paste bait products for German cockroach (Dictyoptera: Blattellidae) control: Laboratory and Field studies. J. Econ. Entomol. **85**(4): 1176-1183.

Bennett, G.W. & C.D. McNeal. 1974. ULV in pest control operations. Pest Control **42**: 12-19.

Brenner, R.J. & R.R. Pierce. 1991. Seasonality of peridomestic cockroaches (Blattoidea: Blattidae): mobility, winter reduction, and effect of traps and baits. J. Econ. Entomol. **84**: 1735-1745.

Grayson, J.M. & W.H. Robinson. 1976. Comparative effectiveness of various insecticides against cockroaches. Pest Control **44**(2): 30-33.

Koehler, P.G., T.H. Atkinson & R.S. Patterson. 1991. Toxicity of abamectin to cockroaches (Dictyoptera, Blattellidae, Blattidae). J. Econ. Entomol. **84**: 1758-1762.

Lane, M.S. & A.G. Appel. 1996. Toxicity, repellence, and effects of starvation compared among insecticidal baits in the laboratory for control of American and Smokybrown cockroaches. J. Econ. Entomol. **89**(2): 402-410.

Lee, D.K. 1993. Field and laboratory studies on the control effects of various poisonousbaits against domestic cockroaches in Korea (II). Sumitomo Chemical, Research Report, 49pp.

Lee, D.K. 1994. Evaluations on the control effects of various insecticidal baits against domestic cockroaches in Korea (I). Sumika Life-Tech., Research Report, 46pp.

Lee, D.K. 1995. Evaluations on the control effects of various insecticidal baits against German and American cockroaches in Korea (II). Sumika Life-Tech., Research Report, 50pp.

Lee, D.K. & J.H. Jun. 1995. Laboratory study of various insecticidal bait products for control of German and American cockroaches. Korean J. Entomol. **25**(4):

305-312.

MacDonald, R.S., G.W. Annette & G.B. Kinoshita. 1987. Control of German cockroaches, *Blattella germanica* L.(Orthoptera: Blattellidae), using hydramethylnon baits in an animal health facility. Proc. Ent. Soc. Ontario **118**: 7-12.

Milio, J.F., P.G. Koehler & R.S. Patterson. 1986. Laboratory and field evaluations of hydramethylnon bait formulations for control of American and German cockroaches (Orthoptera: Blattellidae). J. Econ. Entomol. **79**: 1280-1286.

Moore, R.C. 1973. Cockroach proofing. Bulletin 740. Connecticut Agricultural Experiment Station, New Haven, CT.

Ogg, C.L. & R.E. Gold. 1993. Inclusion of insecticidal bait stations in a German cockroach (Orthoptera: Blattellidae) control program. J. Econ. Entomol. **86**(1): 61-65.

Ree, H.I., D.H. Lee, I.Y. Lee & S.H. Jeon. 1995. Field trial on control effect of poison baits against German cockroaches (*Blattella germanica*). Korean J. Entomol. **25**(3): 219-223.

Reierson, D.A., M.K. Rust, A. VanDyke & A.G. Appel. 1983. Control of German cockroaches with amidinohydrazone bait. Insectic. Acaric. Tests **8**: 54.

Reierson, D.A. & M.K. Rust. 1984. Insecticidal baits and repellency in relation to control of the German cickroach, *Blattella germanica* (L.). Pest Manage. **3**: 26-32.

Rust, M.K. 1986. Managing household pests, pp. 335-368. *In* G.W. Bennett and J.M. Owens (eds.), Advances in urban pest management. Van Nostrand Reinhold, New York.

Rust, M.K. & D.A. Reierson. 1981. Attraction and performance of insecticidal baits for German cickroach control. Int. Pest Control **23**: 106-109.

Shim, J.C. & H.I. Ree. 1982. Field experiment on control effect of permethrin (EKSMIN) against household cockroaches. Korean J. Entomol. **12**(1): 57-60.

Smith, L.M., E.P. Benson, A.G. Appel, T.P. Mack & G.J. Keever. 1994. Controlling cockroaches with less insecticide. Ala. Agric. Res. Stn. Highlights, Agric. Res. **41**: 22-23.

SPSS Incorporated. 1986. SPSS/x user's guide. 2nd ed. McGraw-Hill, N.Y.

Wright, C.G. & H.E. Dupree, Jr. 1988. Evaluation of potential insecticides for controlling German cockroaches, 1986. Insectic. Acaric. Tests **396**: 82.

(Received April 2, 1997, Accepted August 22, 1997)