Evaluations of Sampling Methods for Darkling Beetles (*Alphitobius diaperinus*) in the Litter of Turkey and Broiler Houses[1]

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ABSTRACT Materials placed on the litter in turkey and broiler houses were evaluated as sampling devices for the larvae and adults of *Alphitobius diaperinus* (lesser mealworm or darkling beetle). Insects harbored in, on, and between pieces of the materials were counted after 1-week exposure. Pan traps consisting of two stacked pieces of 1.3-cm thick foil-covered polyisocyanurate insulation (Celotex®) placed under a protective metal pan staked to the litter surface was a more effective sampling device than pan traps using thicker (5 cm) Celotex®, 3.8 cm thick polystyrene (Styrofoam®), or two stacked pieces of wood. A tube trap consisting of rolled fluted corrugated cardboard inserted in a section of polyvinyl chloride pipe was as effective a sampling device as the two pieces of Celotex® in a pan trap and was more convenient to use. Six pieces of corrugated cardboard stacked under a pan caught larger numbers of beetle larvae and adults but was awkward to handle and impractical. Placement of sampling devices in the major subhabitats (open center, near walls, near feeders, and near waterers) in turkey and broiler houses affected catches of beetle larvae and adults. The open center area was satisfactory and most convenient.
(*Key words*: lesser mealworm, darkling beetles, sampling, insulation, litter, turkey, broiler)

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INTRODUCTION

The darkling beetle, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae), is a cosmopolitan pest commonly found in stored grains and flour. The beetle is also known as the lesser mealworm due to the appearance of the larval stage and its frequent occurrence in flour and feed products. The larvae and adults are frequently abundant in poultry manure and litter (Legner and Olton, 1970; MacCreary and Catts, 1954; Pfeiffer and Axtell, 1980). High populations often develop in turkey and broiler houses where new litter is added to old litter that has been only partially removed between flocks (Silberman and Schmittle, 1967; De las Casa *et al.*, 1972; Gould and Moses, 1951; Harein *et al.*, 1972; Lancaster and Simco, 1967).

High populations of *A. diaperinus* in poultry houses sometimes are of concern due to the potential for the insects to harbor pathogens that cause poultry diseases (De las Casa *et al.*, 1968, 1973, 1976; Eidson *et al.*, 1965, 1966). Although the insect does not damage healthy birds, both adults and larvae will feed on dead or dying chicks (Harding and Bissell, 1958; Eidson *et al.*, 1965).

Alphitobius diaperinus tunnel into the insulation of the buildings causing heat losses and eventually necessitating costly replacement of the insulation (Ichinose *et al.*, 1980; Pfeiffer, 1978). Both polyurethane and polystyrene insulating materials have been observed to be heavily damaged by the tunnelling caused mostly by larvae (Ichinose *et al.*, 1980).

Attempts to develop methods for controlling the beetles in poultry houses have been hampered by the absence of a practical, quantitative method for sampling the insect populations. Tedious counting methods and crude indices have been used (Harding and Bissell, 1958; Simco *et al.*, 1966). Therefore, field experiments were conducted to evaluate several types of sampling devices and their placement in poultry houses to develop a practical method for routine monitoring of *A. diaperinus* populations. Such monitoring is needed to determine when chemical control measures or other management practices are needed and to determine the effectiveness of any measures that are used.

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MATERIALS AND METHODS

Experiment 1. The experiment was conducted in two turkey grow-out houses (12 × 121 m) in Duplin County, NC containing Double Diamond poults (2 weeks old at the beginning of the experiment) and two broiler houses (12 × 91 m) in Chatham County, NC containing Shaver chicks (3 weeks old at the beginning of the experiment). All houses contained deep litter (wood shavings) over a soil substrate. At the beginning of the experiment, the turkey houses had 12-cm deep litter added after cleaning out the used litter and before adding the new flocks; broiler houses had 3-cm deep litter placed on top of 15-cm old litter, which had been used 10 weeks by the previous flocks. The experiment was conducted for 4 weeks (July 22 to August 9, 1981).

Four building materials used in poultry house construction were compared as sampling devices for beetle larvae and adults. Pieces of the materials, 14 × 24 cm, were laid on the litter surface under protective metal pans for 1-week. The materials were: 1) two stacked pieces of 1.3-cm thick (.5 in), foil-covered polyisocyanurate insulation (Celotex®, Georgia-Pacific Corp.), 2) one piece of 5-cm thick (2 in), foil-covered polyisocyanurate insulation (Celotex®, Georgia-Pacific Corp.), 3) one piece of 3.8-cm thick (1.5 in) polystyrene insulation (Styrofoam®, Dow Chemical Co.), and 4) two stacked pieces of 1.3-cm thick (.5 in) pine board. A pine board was placed on top of the two thinnest insulation materials to assure firm contact of materials with the litter. Each of the four sampling materials lying on the litter was covered with an inverted metal pan held in place by two metal stakes to prevent movement or overturning by the birds (Fig. 1).

The four sampling materials were placed ca. 4 m apart in a 4 × 4 Latin square design in each of the four houses. At weekly intervals for 4 weeks the pans and sampling materials were removed and replaced with new units. When the materials were picked up from the litter, the numbers of adult and larval *A. diaperinus* observed on the litter beneath the sampling device were estimated using a numerical index: 0 = no insects, 1 = 1 to 10 insects, 2 = 11 to 100 insects, 3 = 100 to 1000, 4 = 1000 to 10,000, 5 = 10,000 to 20,000, 6 = over 20,000. Upon removal, each pan and sampling material was sealed in a plastic bag, returned to the laboratory, and frozen overnight to kill the insects. After thawing, all of the adults and larvae of *A. diaperinus* in each sample were counted, including those tunnelled into the material. These counts were transformed to log (x + 1) and analyzed using a two-way analysis of variance and Duncan's multiple range procedure to determine significant differences (Barr *et al.*, 1979). The relative variability (coefficient of variability) of the untransformed means was calculated by $RV = \frac{s_{\bar{x}}}{\bar{x}} \times 100$ (Ruesink, 1980), and significant differences were determined by Duncan's multiple range procedure after analysis of variance. Indices of beetle abundance were analyzed without transformation.

Experiment 2. Two turkey houses (12 × 121 m) in Duplin County, NC, which contained Nichols poults (2 weeks old at the beginning of the experiment) with 12-cm deep litter (wood shavings that had been in the houses for 12 weeks under a previous flock) over a soil substrate were used. The partial house brooding method (poults were restricted to half of the house for the first 5 weeks) was used; therefore, the experiment was conducted in the portion of the house used for brooding. The experiment was conducted for 4 weeks (June 2 to June 30, 1982).

Three materials were compared as sampling devices for beetle larvae and adults when the devices were placed on the litter surface for 1-week periods. The materials were: 1) two stacked pieces of 1.3-cm (.5 in) thick, foil-covered polyisocyanurate insulation, the same as used in Experiment 1, 2) six stacked pieces of .5-cm thick (.187 in) one-faced AA flute

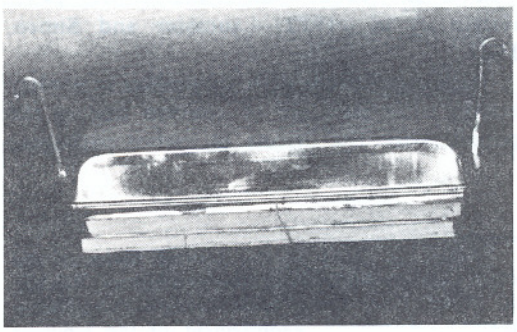

FIG. 1. Pan trap with two stacked pieces of 1.3-cm thick, foil-covered polyisocyanurate insulation (Celotex®).

corrugated cardboard), and 3) a 3.8-cm (1.5 in) diameter roll of the .5-cm thick AA flute corrugated cardboard. The stacked pieces of insulation and cardboard were 14 × 24 cm and protected on the litter by an inverted metal pan, which was staked in place. The rolled piece of cardboard (20 × 30 cm) was inserted into a piece of rigid polyvinyl-chloride (PVC) pipe (23 cm long × 3.8 cm diameter). Holes were drilled in each end of the pipe and metal stakes inserted to hold the pipe in place on the litter (Fig. 2). This tube sampling device was suggested by J. J. Arends.

The three sampling devices were placed on the litter in a group ca. 1 m apart with seven groups in each of three rows in each of the two houses. At weekly intervals for 4 weeks the devices were removed and replaced with new ones. When the devices were picked up they were immediately sealed in plastic bags, returned to the laboratory and frozen overnight to kill the insects. After thawing, the adults and larvae of *A. diaperinus* in each sample were counted. These counts were transformed to log $(x + 1)$ prior to statistical analysis as in Experiment 1. The relative variability of the untransformed means was calculated and analyzed as in Experiment 1.

Experiment 3. The effect of sampling location (subhabitat) within turkey and broiler houses was determined by using the sampling device consisting of two pieces of stacked 1.3 cm thick polyisocyanurate insulation placed on the litter under an inverted pan as described in Experiment 1. The same houses (two turkey and two broiler) as described in Experiment 1 were used, but conditions differed, since Experiment 3 was conducted later when new flocks of birds were placed in the houses after the old litter was removed from all four houses and new litter added. Prior to adding the new litter the turkey houses were sprayed with disinfectant (cresylic acid) and the broiler houses were treated with insecticide dust (carbaryl). The experiment was conducted for the period in which birds were in the houses: 12 weeks for the turkeys (August 25 to November 17, 1981) and 5 weeks for the broilers (September 2 to October 7, 1981).

The two turkey houses were the same style construction. Each had a 1-m high block foundation wall, screened sides with adjustable curtains to control air flow, and metal roofs. Both had 1-week-old Nichols poults at the beginning of the experiment, and the poults were housed in one-half of the house for the first 5 weeks. Therefore, the experiment was conducted only in that half of the house. Two rows of wooden posts, each 4 m from the outside walls, supported the roof. A row of automatic waterers (3 m apart) was located 3 m from each wall. A row of automatic feeders (1 m apart) was located 2 m from each wall.

The two broiler houses were the same style of construction. Each had a 1-m high block foundation wall, screened sides with adjustable curtains, and metal roofs. Both had 1-week-old Shaver chicks at the beginning of the experiment. Two rows of wooden posts, each 4 m from the outside walls, supported the roof. A row of automatic waterers (4 m apart) was located 2 m from each wall. A row of trough feeders was located 3 m from each wall.

The sampling device was placed on the litter in four subhabitats: 1) near the walls, 2) near the feeders, 3) near the waterers, and 4) in the open center between the two rows of posts. The devices were placed in these subhabitats along three equally spaced transects across the width of each house. Consequently there were six samples per subhabitat per house. At weekly intervals the sampling devices were removed and

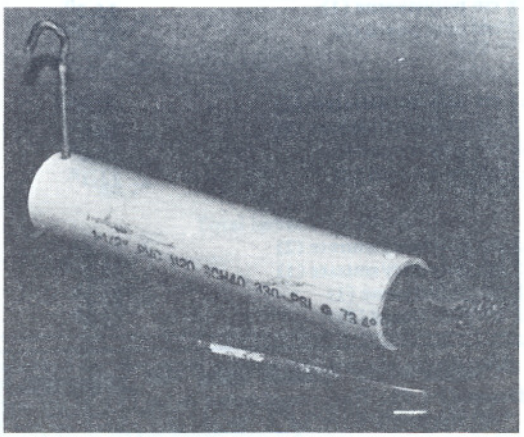

FIG. 2. Tube trap with insert of rolled corregated cardboard.

replaced with new ones in approximately the same location. When the devices were picked up they were immediately sealed in plastic bags, returned to the laboratory, and frozen overnight to kill the insects. After thawing, the adults and larvae of *A. diaperinus* in each sample were counted. These counts were transformed to log (x + 1) prior to statistical analysis as in Experiments 1 and 2.

RESULTS

Experiment 1. The indices of abundance of larvae and adults observed under the sampling materials were analyzed for the four houses, and there were no significant differences ($P<.05$) among the sampling methods. Mean indices ranged from 2.6 to 5.2. It was very difficult to assign an index of observed abundance due to the rapid movement of larvae and adults into the litter as soon as the sampling device was lifted. Detection of population differences using indices was not successful.

The four sampling materials trapped appreciable numbers of larvae and adults, which could easily be counted, especially after freezing. Significant differences among the four sampling methods were not consistent among the four houses (Table 1). However, generally the most larvae and adults were collected from the sampling device consisting of two pieces of 1.3-cm thick polyisocyanurate. The greater number of larvae recovered by this method was significantly different from the numbers recovered by the other methods in three out of the four houses. The relative variation (coefficient of variation) was calculated weekly for the four sampling methods and there were no significant differences ($P<.05$). Calculated for the entire period of the experiment, the relative variation for larvae was not significant for the four methods (range = 45.1 to 59.9%) and for adults the only significant difference ($P<.05$) was between the two pieces of polyisocyanurate and the two pieces of board. Thus, based on the numbers recovered and the relative variation, the sampling device using two pieces of 1.3-cm thick foil-covered polyisocyanurate was more satisfactory than the other three methods.

The numbers of larvae and adults actually tunnelling into the sampling materials (as opposed to being on the surface or between

TABLE 1. *Mean numbers of Alphitobius diaperinus recovered per sample using four materials placed on the litter in turkey (1 and 2) and broiler (3 and 4) houses*

Sampling material[1]	Mean no. per sample per house[2]			
	1	2	3	4
			Larvae	
1.3 cm polyisocyanurate (2)	72.1^{a}	24.9^{a}	127.0^{a}	166.4^{a}
5 cm polyisocyanurate (1)	43.3^{b}	18.1^{a}	15.0^{b}	6.2^{b}
3.8 cm polystyrene (1)	16.2^{b}	6.2^{b}	10.0^{b}	5.4^{b}
1.3 cm pine board (2)	14.2^{b}	3.4^{b}	67.3^{a}	14.2^{b}
			Adults	
1.3 cm polyisocyanurate (2)	22.4^{a}	16.5^{a}	115.8^{a}	79.9^{a}
5 cm polyisocyanurate (1)	26.0^{a}	29.0^{a}	52.0^{a}	40.1^{ab}
3.8 cm polystyrene (1)	20.0^{a}	20.5^{a}	60.1^{a}	51.0^{a}
1.3 cm pine board (2)	11.1^{a}	6.1^{b}	71.7^{a}	29.7^{b}
			Total larvae plus adults	
1.3 cm polyisocyanurate (2)	94.5^{a}	24.9^{a}	242.8^{a}	246.3^{a}
5 cm polyisocyanurate (1)	43.3^{ab}	47.2^{a}	67.0^{b}	46.3^{b}
3.8 cm polystyrene (1)	36.3^{b}	26.8^{a}	70.1^{b}	56.5^{b}
1.3 cm pine board (2)	25.4^{b}	9.5^{b}	139.1^{ab}	44.0^{b}

[a,b]Means within columns under each subheading followed by the same superscript are not significantly different ($P<.05$). Data transformed to log (x + 1) for statistical analysis.

[1]All materials were 14 × 24 cm and placed on the litter beneath an inverted metal pan. Polyisocyanurate was foil covered (Celotex®). Polystyrene (Styrofoam®) was not covered. Number of pieces in parentheses.

[2]Each mean based on 16 samples (four samples per house per week repeated for 4 weeks).

TABLE 2. *Mean numbers of Alphitobius diaperinus (larvae and adults) tunnelled into sampling materials placed on the litter in turkey (1 and 2) and broiler (3 and 4) houses*

Sampling material[1]	Mean no. tunnelled per sample per house[2]			
	1	2	3	4
1.3 cm polyisocyanurate (2)	16.5^{a}	10.7^{ab}	8.8^{ab}	11.6^{b}
5 cm polyisocyanurate (1)	14.5^{a}	14.5^{a}	15.3^{a}	15.5^{a}
3.8 cm polystyrene (1)	10.2^{a}	3.3^{b}	2.8^{bc}	5.6^{b}
1.3 cm pine board (2)	$.2^{b}$	$.1^{c}$	$.7^{c}$	0^{c}

^{a,b,c}Means within columns under each subheading followed by the same superscript are not significantly different ($P<.05$). Data transformed to log ($x + 1$) for statistical analysis.

[1] All materials were 14 × 24 cm and placed on the litter beneath an inverted metal pan. Polyisocyanurate was foil covered (Celotex®). Polystyrene (Styrofoam®) was not covered. Number of pieces in parentheses.

[2] Each mean based on 16 samples (four samples per house per week repeated for 4 weeks).

the pieces) varied among the four houses (Table 2). The highest numbers were generally in the foil-covered polyisocyanurate, especially the 5-cm thick piece. The polystyrene insulation was tunnelled to a lesser extent, and this was significantly different ($P<.05$) from the 5-cm polyisocyanurate in three out of the four houses. The least tunnelling was in the pine boards, and this was significantly less ($P<.05$) than for the polyisocyanurate insulation in all four houses and for the polystyrene in three out of the four houses.

Experiment 2. The corrugated cardboard sampling device recovered more larvae and adults than the two pieces of 1.3-cm thick polyisocyanurate (Table 3). Although the six pieces of corrugated cardboard recovered the largest number, that method was inconvenient because the pieces were awkward to handle. The number of larvae recovered, however, was significantly greater ($P<.05$) than by the other two sampling methods. There were no significant differences in numbers of adults recovered by the three methods. The rolled cardboard inserted in a PVC tube

TABLE 3. *Mean numbers of Alphitobius diaperinus recovered per sample per week using three materials placed on the litter in two turkey houses*

Sampling material[1]	Mean no. per sample per house[2]	
	1	2
	Larvae	
1.3 cm polyisocyanurate (2)	94.5^{b}	95.8^{b}
.5 cm corrugated cardboard (6)	661.1^{a}	653.9^{a}
.5 cm corrugated cardboard (rolled)	117.4^{b}	129.1^{b}
	Adults	
1.3 cm polyisocyanurate (2)	48.2^{a}	76.8^{a}
.5 cm corrugated cardboard (6)	132.1^{a}	117.3^{a}
.5 cm corrugated cardboard (rolled)	60.7^{a}	87.3^{a}
	Total larvae plus adults	
1.3 cm polyisocyanurate (2)	142.7^{b}	172.7^{b}
.5 cm corrugated cardboard (6)	793.2^{a}	771.2^{a}
.5 cm corrugated cardboard (rolled)	178.2^{a}	216.5^{b}

^{a,b}Means within columns under each subheading followed by the same superscript are not significantly different ($P<.05$). Data transformed to log ($x + 1$) for statistical analysis.

[1] Pieces of foil covered polyisocyanurate (Celotex®) and cardboard were 14 × 24 cm and placed on the litter beneath an inverted metal pan. Rolled cardboard was a piece 20 × 30 cm rolled into a diameter of 3.8 × 20 cm long and inserted into an open-ended piece of PVC pipe placed on the litter.

[2] Each mean based on 84 samples (21 samples per house per week repeated for 4 weeks).

was not significantly different from the two pieces of 1.3-cm thick polyisocyanurate in the number of larvae recovered. This method ("Arends tube trap") was convenient due to the ease in handling. The relative variation was calculated for the three sampling methods, and for the larvae and adults there was no significant difference ($P<.05$) between the tube trap (range 10.9 to 12.4%) and the pan trap with two pieces of 1.3-cm thick polyisocyanurate (range = 12.4 to 12.8%). The relative variation for the pan trap with six pieces of cardboard was 14.0 to 24.2%, which made that method the least satisfactory of the three. The Arends tube trap was the most satisfactory because of its convenience and because the relative variation was not significantly different from the pan trap with two pieces of insulation.

Experiment 3. Location of a sampling device in turkey or broiler houses will affect the numbers of larvae and adults of *A. diaperinus* collected (Table 4). In the turkey houses, significantly ($P<.05$) more larvae and adults combined were recovered from the open center area. In the broiler houses, there was no significant difference in one house and significantly ($P<.05$) fewer larvae and adults combined in the center and near the waterers than in the other two subhabitats in the second house. Because substantial numbers of larvae and adults were collected in all four subhabitats, any could be used as a sampling location. However, because the numbers varied among the subhabitats, it would be necessary to use the same areas consistently when monitoring populations of *A. diaperinus*.

DISCUSSION

The data from these experiments show that larval and adult populations of *A. diaperinus* in turkey and broiler litter may be effectively sampled by using "pan traps" consisting of pieces of insulation material laid on the litter under a protective staked metal pan. Greatest beetle collection was generally made by using two pieces of 1.3-cm thick foil-covered polyisocyanurate (Celotex®) stacked one upon the other. This sampling method has the disadvantage of being rather awkward, because the pans and pieces of insulation are bulky. Use of rolled (3.8 cm diameter × 20 cm long) corrugated cardboard inserted in a 3.8-cm diameter PVC pipe is an equally effective sampling method and much more convenient to handle. It is suggested that this Arends tube trap be used as a routine monitoring method for *A. diaperinus* in poultry litter.

The number of tube traps or pan traps (with two pieces of polyisocyanurate insulation) required for a given level of reliability in sampling was calculated from the data in Experiment 2 by determining the equation for the relationship between log $\bar{x}$ and log $s_{\bar{x}}^2$ by least square linear regression and using the general formula (3) for the coefficient of variability given by Karandinos (1976). As shown in Table 5 (from the simulation over the range (0 to 400) of beetle densities present in Experiment 2), the number of traps required for a given level of variability is greater at low densities than at high densities of beetles. The pan traps are less variable (i.e., fewer traps needed for a given level of variability) than the tube traps at low

TABLE 4. *Mean numbers of Alphitobius diaperinus recovered per sample (pan trap with 2 pieces of insulation) per week from four litter subhabitats in turkey (1 and 2) and broiler (3 and 4) houses*

Subhabitat	Mean no. per sample per house[1]			
	1	2	3	4
	Larvae			
Open center	77.7[a]	38.1[a]	127.6[a]	17.1[a]
Near feeders	20.9[c]	25.1[b]	77.8[a]	17.7[a]
Near waterers	20.0[c]	15.5[b]	74.7[a]	12.1[a]
Near walls	38.0[b]	32.8[a]	57.8[a]	19.5[a]
	Adults			
Open center	82.7[a]	45.1[a]	67.1[b]	13.3[b]
Near feeders	28.4[c]	29.5[b]	82.2[ab]	26.2[a]
Near waterers	52.8[b]	30.4[ab]	75.4[ab]	12.2[b]
Near walls	36.8[c]	23.7[b]	100.2[a]	42.0[a]
	Total larvae plus adults			
Open center	159.5[a]	83.3[a]	194.8[a]	30.5[b]
Near feeders	49.4[c]	54.6[b]	160.0[a]	43.9[a]
Near waterers	72.9[b]	45.9[b]	150.1[a]	24.3[b]
Near walls	74.8[b]	56.5[b]	158.1[a]	61.6[a]

[a,b,c]Means within columns under each subheading followed by the same superscript are not significantly different ($P<.05$). Data transformed to log $(x + 1)$ for statistical analysis.

[1] Each mean based on 72 samples for the turkey houses 1 and 2 (6 samples per subhabitat per week per house repeated for 12 weeks) and 30 samples for the broiler houses 3 and 4 (6 samples per subhabitat per week per house for 5 weeks).

TABLE 5. *Number of samples (tube or pan traps) required at different beetle (adults and larvae combined) densities (mean per sample) for 5 levels (10 to 50%) of relative variability*

Beetle density	Tube trap					Pan trap				
	10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
1	531.6	132.9	59.1	33.2	21.3	150.8	37.7	16.8	9.4	6.0
5	263.5	65.9	29.3	16.5	10.5	113.2	28.3	12.6	7.1	4.5
10	194.8	48.7	21.6	12.2	7.8	100.0	25.0	11.1	6.3	4.0
20	144.0	36.0	16.0	9.0	5.8	88.4	22.1	9.8	5.5	3.5
40	106.4	26.6	11.8	6.6	4.3	78.1	19.5	8.7	4.9	3.1
60	89.2	22.3	9.9	5.6	3.6	72.7	18.2	8.1	4.5	2.9
80	78.6	19.7	8.7	4.9	3.1	69.1	17.3	7.7	4.3	2.8
100	71.4	17.8	7.9	4.5	2.9	66.4	16.6	7.4	4.1	2.7
150	59.8	14.9	6.6	3.7	2.4	61.7	15.4	6.9	3.9	2.5
200	52.7	13.2	5.9	3.3	2.1	58.6	14.7	6.5	3.7	2.3
250	47.8	12.0	5.3	3.0	1.9	56.4	14.1	6.3	3.5	2.3
300	44.2	11.0	4.9	2.8	1.8	54.6	13.6	6.1	3.4	2.2
350	41.3	10.3	4.6	2.6	1.7	53.1	13.3	5.9	3.3	2.1
400	39.0	9.7	4.3	2.4	1.6	51.8	13.0	5.8	3.2	2.1

beetle densities ($\bar{x}$/sample = 100 and below), while the tube traps are less variable at high beetle densities (>100). Because at high beetle densities ($\bar{x}$/sample ⩾400 and RV = 20%) ca. 10 tube traps or 13 pan traps are needed, these numbers of traps are suggested for routine monitoring.

The attempt to use indices of observed numbers of beetle larvae and adults on the litter under the sampling materials showed that this method is useless in a monitoring program.

An important factor in monitoring *A. diaperinus* populations is the consistent placement of the sampling devices in similar subhabitats within the house. Of the subhabitats tested (open center, near waterers, near feeders, near walls), all yield substantial numbers of beetle larvae and adults, but generally the largest numbers were from sampling devices placed in the open center. This is consistent with the observation by Gould and Moses (1951) that more beetles can be found in loosely packed than tightly packed litter. Around feeders and waterers there is a tendency for the litter to become tightly packed. Sampling in the center area of a house is slightly easier and faster than placing the sampling devices near the walls, feeders, or waterers. It is suggested that routine monitoring of *A. diaperinus* populations be done by placing the sampling devices in the open center area of turkey and broiler houses.

It is not possible from the data available to relate the numbers of beetle larvae and adults to actual population levels in the litter. However, the relative changes in mean numbers of larvae and adults per sample per week are useful indicators of the need for control measures or the effectiveness of any control measures that have been used.

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