Effect of Trap Size on Efficiency of Yellow Sticky Traps for Sampling Western Corn Rootworm (Coleoptera: Chrysomelidae) Adults in Corn[1]

R. R. Youngman, T. P. Kuhar, and D. G. Midgarden[2]

Department of Entomology
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0319 U.S.A.

J. Entomol. Sci. 31(3): 277-285 (July 1996)

ABSTRACT Field studies were conducted in Virginia cornfields in 1990 and 1991 to evaluate the effect of trap size on numbers of *Diabrotica virgifera virgifera* LeConte adults caught on unbaited Pherocon AM and Olson yellow sticky traps. No significant differences in trapping efficiency (i.e., catch per unit area) were detected on Pherocon AM traps whose sizes had been reduced by either 50% or 75% when compared with standard Pherocon AM no-bait traps. Likewise, no significant difference in trapping efficiency was detected between Olson traps whose sizes had been reduced 50% and full-size Olson traps (212.9 cm^2). However, significantly more western corn rootworm adults per unit area were caught on Olson yellow sticky traps compared to Pherocon AM traps whose sizes had been reduced 50%. Comparative costs and precision values for reduced-size Pherocon AM and Olson yellow sticky traps are discussed.

KEY WORDS *Diabrotica virgifera virgifera,* yellow sticky traps, field corn

For years, whole-plant counts of corn rootworm adults, *Diabrotica* spp. (Coleoptera: Chrysomelidae), have been advocated as a means of determining the need for larval control in cornfields the following year (Chiang and Flaskerd 1965, Pruess et al. 1974, Roselle 1977). Pruess et al. (1974) reported that a mid-summer population density of one corn rootworm adult per plant was an acceptable economic threshold for determining the need for larval control the following year. This threshold was shown later to be more than 80% accurate in predicting cornfields at risk to corn rootworms (Roselle 1977). Subsequent studies involving sequential sampling methods (Foster et al. 1982), comparative costs and variance components of different sampling methods (Steffey et al. 1982), dispersion patterns (Steffey and Tollefson 1982), and reevaluation of the accuracy of economic threshold prediction (Stamm et al. 1985) have helped improve the overall efficiency of the whole-plant count method.

[1] Received 16 October 1995; Accepted for Publication 25 April 1996.

[2] Carambola Fruit Fly Project, Cultuurtuinlan 11, Paramaribo, Suriname

More recent studies (Hein and Tollefson 1984, 1985, Karr and Tollefson 1987) have focused on relative sampling methods in which the number of corn rootworm adults caught on sticky traps is used as an alternative to whole-plant counts. In evaluating several trapping techniques, Hein and Tollefson (1984) showed that the Pherocon AM trap was an adequate tool for sampling corn rootworm adults. The Pherocon AM trap costs about one dollar and consists of a yellow cardboard panel that is pre-coated on one side with sticky adhesive.

Hein and Tollefson (1985) suggested that 12 Pherocon AM traps be used per field (regardless of field size) to obtain a standard error within 10% of the mean. They also suggested that traps be installed during the last 3 wk of August and replaced every 7 d. However, this sampling scheme is cost effective only for large cornfields (i.e., >10ha). For example, for a 3 wk sampling interval, trap costs alone (about $36.00) represent nearly 25% of the total cost of preventively applying a granular insecticide to a 4-ha cornfield (assuming a granular insecticide cost of $37.00 per ha) compared to less than 10% for a 10-ha cornfield.

Reducing scouting costs as much as possible is essential when developing pest management programs for relatively low value crops such as field corn. This is particularly true of corn grown throughout the ridge and valley terrain of western Virginia where fields are typically between 5 and 6 ha in size (R.R.Y., upub. data). The purpose of this study was to evaluate the trapping efficiency of two commercial brands of yellow sticky traps whose sizes had been reduced to determine if scouting costs for western corn rootworm, *Diabrotica virgifera virgifera* LeConte, could be reduced without sacrificing sampling accuracy.

Materials and Methods

1990 Pherocon AM Half-Trap Experiment. The treatments evaluated in this experiment consisted of a standard Pherocon AM (Trécé, Salinas, CA) no-bait trap and a modified Pherocon AM no-bait trap that we cut in half. The standard AM trap consisted of a 22.9 × 28.0 cm yellow cardboard panel (641.2 cm^2) with a smaller, 17.7 × 22.8 cm rectangular grid (403.6 cm^2) that was coated with Tangletrap adhesive (Tanglefoot Co., Grand Rapids, MI). The standard AM trap comes folded in half at the midpoint of the long side of the panel so that both yellow halves of a trap are stuck together. When used in cornfields to monitor corn rootworms, the standard AM trap is unfolded and bent back around a corn stalk so that each half of the yellow sticky panel is exposed. We constructed Pherocon AM half traps by cutting a standard AM trap along its prefolded crease into two equal sections. For this experiment, the entire yellow sides of the standard and Pherocon AM half traps were coated with Tangletrap adhesive, which provided effective trapping areas of 641.2 cm^2 and 320.6 cm^2, respectively.

We selected a 12-ha field with corn planted on 0.76-m rows in Augusta Co., Virginia. The field had been in continuous corn production since 1987 and was not treated with a soil insecticide at planting in 1990. Each treatment pair of traps was placed 3 m apart along two rows near the center of the field. Traps were attached to corn stalks with a 5.1-cm roofing nail approximately 1.2 m above the ground. Treatments were replicated 15 times, and adjacent pairs of treatments were separated from one another by a distance of 15 m.

The experiment was conducted over three consecutive wks during which we placed new traps in the field on 18 July, 25 July, and 1 August. All treatment pairs of traps were randomized when placed in the field and rerandomized at each sample date. After each 7-d interval, the number of western corn rootworm adults per trap was recorded. Trap catch data for the Pherocon AM half traps were multiplied by 2 to adjust for the size of the standard AM trap prior to statistical analysis. A paired *t*-test was used to analyze the data for each wk after $(x)^{1/2}$ transformation.

1990 Pherocon AM Quarter-Trap Experiment. The treatments evaluated in this experiment consisted of the standard Pherocon AM trap described previously and a Pherocon AM quarter trap. We constructed Pherocon AM quarter traps by cutting a Pherocon AM half trap into two equal sections. As in the previous study, the entire yellow sides of the standard and Pherocon AM quarter traps were coated with Tangletrap adhesive. The effective trapping area of the Pherocon AM quarter trap was 160.3 cm^2.

The experiment was conducted in the same Augusta Co. cornfield and followed the same procedures as described previously with the following changes: treatments were replicated 30 times, and the experiment was run for one 7-d period from 8 to 15 August. Trap count data for the Pherocon AM quarter traps were multiplied by 4 to adjust for the size of the standard AM trap prior to statistical analysis. A paired *t*-test was used to analyze the data after $(x)^{1/2}$ transformation.

1991 Olson Trap Experiment. Results of a preliminary experiment (R. R. Y., unpubl. data) indicated that a less expensive yellow sticky trap (Olson Products Inc., Medina, OH) caught over twice as many western corn rootworm adults as the Pherocon AM half trap. Therefore, our 1991 experiment further investigated differences in western corn rootworm trap catch efficiency between the Pherocon AM half trap and the Olson trap. Unlike the Pherocon AM trap which is made from cardboard stock, the Olson trap is made for 12-mil yellow polystyrene panels. Another difference between Pherocon AM and Olson yellow sticky traps is that both sides of the Olson trap are coated with Sticky Stuff adhesive (Olson Products Inc., Medina, OH). Silicone-coated release paper is used to protect the adhesive sides of the Olson trap, which allows one side to be used at a time, in effect doubling the life of a trap.

The Olson trap used in this experiment was 15.2 × 15.2 cm and was installed on corn stalks in the same manner as the Pherocon AM traps. However, to improve handling of the Olson traps, the manufacturer left a 1.3-cm wide, adhesive-free margin along one edge of both sides of every trap. Thus, the effective trapping area of the Olson yellow sticky trap used in this experiment was 212.9 cm^2. Three versions of the Olson trap were compared to the Pherocon AM half trap: (1) Olson "new" trap (first side of trap exposed at start of trapping interval; second side of trap protected with release paper and positioned against corn stalk); (2) Olson "wk-old" trap (second side of trap exposed at start of trapping interval; first side of trap [with wk-old catch of corn rootworm adults and other insects] positioned against corn stalk); and (3) Olson "new" half trap (first side of trap exposed at start of trapping interval; second side of trap protected with release paper and positioned against corn stalk; and trap size was one-half that of Olson "new" trap).

The experiment was conducted in 1991 in two cornfields in Craig Co. ("Old" field and "Givens" field) and one in Augusta Co. ("Reeves" field). These cornfields ranged in size from 3.2 to 5.7 ha and had been in continuous corn production for 3 to 5 yr. Fields were planted on 0.76- or 0.91-m rows without a soil insecticide. The four aforementioned treatments were applied according to a randomized complete block design with 12 replications. Traps were deployed in each field for 1 wk according to the procedures described previously with the exception that all adjacent traps and blocks were spaced approximately 12 m apart. Trap count data for each field were analyzed separately using a two-way analysis of variance (ANOVA) with blocks and treatments as factors after $(x + 0.5)^{1/2}$ transformation, and after the data for the Olson treatments were adjusted according to the size of the Pherocon AM half trap. The treatment source of variation was partitioned into three orthogonal contrasts (Steel and Torrie 1980).

Results

1990 Pherocon AM Half-Trap Experiment. Over the 3-wk course of the experiment, the standard Pherocon AM traps averaged 51.5 ± 1.4 ($\bar{x}$ ± SEM) western corn rootworm adults per wk compared to an adjusted average of 50.5 ± 2.2 for the Pherocon AM half traps (Fig. 1). Numerically more western corn rootworm adults were caught on standard AM traps (53.8 ± 5.8) than on AM half traps (46.3 ± 6.8) on the first sample date (25 July); however, the difference was not significant (t = 1.01; df = 26; P = 0.32). On the second sample date (1 August), the AM half traps averaged more western corn rootworm adults (53.9 ± 4.8) than the standard AM traps (49.0 ± 4.4), but again the difference was not significant (t = 0.71; df = 28; P = 0.48). By the third sample date (8 August), the difference in numbers of western corn rootworm adults per trap between the standard (51.7 ± 3.4) and AM half traps (51.3 ± 5.1) was <1% (t = 0.23; df = 28; P = 0.82).

1990 Pherocon AM Quarter-Trap Experiment. There was no significant difference (t = 0.23; df = 58; P = 0.82) between th numbers of western corn rootworm adults caught per trap on the standard and AM quarter traps at the end of the 7-d sample period on 15 August. The standard AM traps caught an average of 73.2 ± 4.1 western corn rootworm adults per trap compared to an adjusted average of 72.5 ± 5.0 for the AM quarter traps; a difference of <1%. The results of this experiment, as well as those of the previous experiment, suggest that trap catch efficiency of western corn rootworm adults on Pherocon AM traps is directly proportional to trap size.

1991 Olson Trap Experiment. The highest average number of western corn rootworm adults caught on Pherocon AM half traps in this experiment was 6.8 at the Reeves field in Augusta Co. (Table 1). Despite the relatively low numbers of adults caught on AM half traps, the treatment source of variation for each test site was significant ($P < 0.05$) according to ANOVA. In addition, the orthogonal contrasts between the Pherocon AM half and Olson traps for each test site was highly significant ($P \leq 0.002$) (Tables 1-3). When compared to the AM half trap, the Olson traps averaged 4.3-fold more ($P < 0.001$) western corn rootworm adults per trap at the Reeves field (Table 1); 3.0-fold more ($P < 0.001$) adults per trap at the Old field (Table 2); and 3.3-fold more (P = 0.002) adults

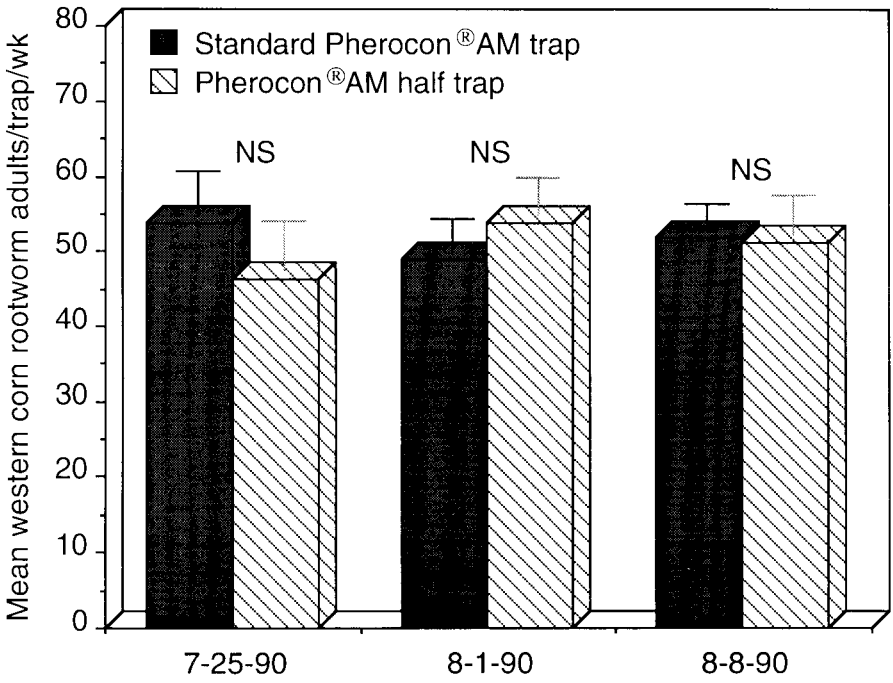

Fig. 1. Comparison of mean numbers of western corn rootworm adults per trap per wk on standard Pherocon AM no-bait and Pherocon AM half traps. Trap catch data for Pherocon AM half traps were adjusted to the trapping area of the standard Pherocon AM trap prior to statistical analysis. A paired *t*-test was used to analyze the data by wk after $(x)^{1/2}$ transformation. Treatment means (± SEM) presented in figure are based on actual data.

per trap at the Givens field (Table 3). Orthogonal contrasts between the Olson new and Olson wk-old trap treatments were not significant ($P > 0.05$) for any of the test sites. This suggests that a previous catch of insects on one side of an Olson trap has minimal effect on the trapping efficiency of the remaining fresh side of the trap over the next trapping interval. Likewise, orthogonal contrasts between the Olson new plus Olson wk-old traps and the Olson new, half trap treatments also were not significant ($P > 0.05$) for any of the test sites.

The SEM for the combined Olson treatments was 3.4 times greater than that of the Pherocon AM half trap in three test sites (Tables 1-3). This is expected given the greater numbers of western corn rootworm adults caught on the Olson traps. However, when averaged across the three test sites, the mean relative variations for the Pherocon AM half (21.3) and Olson new traps (20.8) were similar, indicating a high degree of reliability among the trapping methods.

Table 1. Comparison of numbers of western corn rootworm adults on Pherocon AM and Olson yellow sticky traps after one week; Reeves field, Augusta Co., VA; 1991.

Treatment*	Mean (± SEM)** western corn rootworm adults/ trap	Mean relative variation	Relative net precision†
Pherocon AM new, half trap	6.8 (1.2)	17.42	0.96
Olson new trap	31.0 (5.7)	18.33	1.11
Olson wk-old trap	27.0 (4.8)	17.78	1.14
Olson new, half trap	30.6 (5.2)	16.98	1.20
Orthogonal contrasts			
Pherocon AM new, half trap vs Olson traps	($P < 0.001$)		
Olson new trap vs. Olson wk-old trap	NS		
Olson new + Olson wk-old traps vs. Olson new, half trap	NS		

* ANOVA treatment source of variation was significant ($F = 11.11$; df = 3, 33; $P < 0.001$).

** Means (± SEM) are based on raw data; statistical analysis was performed on $(x + 0.5)^{1/2}$ transformed data. Trap counts for all Olson treatments were adjusted to the size of the Pherocon AM half trap (320.6 cm^2) prior to statistical analysis.

† Total cost of samples (n = 12) used for the Pherocon AM treatment was $6.00 (i.e., $0.50/trap) and, for each of the Olson treatments adjusted to the size of the Pherocon AM half trap, was $4.92 (i.e., $0.41/trap side).

Discussion

Several studies have investigated the relationship of sticky trap size (Heathcote 1957, Staples and Allington 1959, Parrella and Jones 1985, Kirk 1987) on sampling efficiency for various arthropod pests. Heathcote (1957) found that the number of aphids caught per unit area on black or yellow sticky traps decreased as trap size increased. In a sampling efficiency study involving an eriophyid mite, Staples and Allington (1959) showed that smaller grease-coated slides were more efficient per unit area in catching mites than larger slides. Parrella and Jones (1985) investigated the variance/mean relationship of trap catches of an agromyzid fly, *Liriomyza trifolli* (Burgess), on large and small yellow sticky traps in a greenhouse study. They found that the variance/mean relationship of trap catches was very consistent over time for both large or small traps. Also, Kirk (1987) showed that the number of *Thrips imaginis* Bagnall caught on white sticky traps increased according to a constant power of trap size.

One measure of sampling efficiency involving sticky traps is catch per unit area. In our study, efficiency of the modified Pherocon AM half and quarter traps did not differ from the standard AM trap, indicating that western corn

Table 2. Comparison of numbers of western corn rootworm adults on Pherocon AM and Olson yellow sticky traps after one week; Old field, Craig Co., VA; 1991.

Treatment*	Mean (± SEM)** western corn rootworm adults/ trap	Mean relative variation	Relative net precision†
Pherocon AM new, half trap	6.2 (1.6)	25.30	0.65
Olson new trap	20.6 (6.0)	28.96	0.70
Olson wk-old trap	18.2 (3.1)	16.81	1.21
Olson new, half trap	16.1 (3.7)	22.93	0.89
Orthogonal contrasts			
Pherocon AM new, half trap vs Olson traps	($P < 0.001$)		
Olson new trap vs. Olson wk-old trap	NS		
Olson new + Olson wk-old traps vs. Olson new, half trap	NS		

* ANOVA treatment source of variation was significant ($F = 5.14$; df = 3, 33; $P < 0.005$).

** Means (± SEM) are based on raw data; statistical analysis was performed on $(x + 0.5)^{1/2}$ transformed data. Trap counts for all Olson treatments were adjusted to the size of the Pherocon AM half trap (320.6 cm^2) prior to statistical analysis.

† Total cost of samples (n = 12) used for the Pherocon AM treatment was $6.00 (i.e., $0.50/trap) and, for each of the Olson treatments adjusted to the size of the Pherocon AM half trap, was $4.92 (i.e., $0.41/trap side).

rootworm scouting costs may be reduced by reducing trap size. Similarly, we found no difference in efficiency between Olson new and wk-old traps or the Olson new, half trap. However, all three Olson trap treatments caught significantly more western corn rootworm adults per unit area than the Pherocon AM half trap.

Another measure of sampling efficiency is relative net precision (RNP), defined by the equation: $RNP = 100/(RV)(C_s)$; where RV is relative variation and C_s is the total cost of the n samples used to calculate RV (Ruesink 1980). In our study, n = 12 and C_s was $6.00 for the AM half trap treatment and $4.92 for each of the Olson treatments adjusted to the size of the AM half trap. Labor costs associated with the placement, retrieval, and inspection of traps were not included in the calculation of RNP because differences in these costs among the trapping methods were negligible.

Relative net precision values for the Olson new and wk-old traps were higher than those of the Pherocon AM half trap for all three test sites (Tables 1-3). When averaged across the test sites, the RNP of the AM half trap was 0.80 compared to 1.05 for the Olson new trap and 1.19 for the Olson wk-old trap. Although lower in the Givens field (Table 3), the average RNP of 0.90 for the Olson new, half trap also exceeded that of the AM half trap. At current prices, a 10.2 × 15.2 cm Olson yellow sticky trap (155 cm^2 surface area) costs about $0.40, and is being used in a grower-supported

Table 3. Comparison of numbers of western corn rootworm adults on Pherocon AM and Olson yellow sticky traps after one week; Givens field, Craig Co., VA; 1991.

Treatment*	Mean (± SEM)** western corn rootworm adults/ trap	Mean relative variation	Relative net precision†
Pherocon AM new, half trap	2.4 (0.5)	21.07	0.79
Olson new trap	6.9 (1.0)	15.12	1.34
Olson wk-old trap	8.8 (1.5)	16.53	1.23
Olson new, half trap	8.0 (2.7)	33.46	0.61
Orthogonal contrasts			
Pherocon AM new, half trap vs Olson traps	($P < 0.002$)		
Olson new trap vs. Olson wk-old trap	NS		
Olson new + Olson wk-old traps vs. Olson new, half trap	NS		

* ANOVA treatment source of variation was significant ($F = 4.29$; df = 3, 33; $P < 0.012$).

** Means (± SEM) are based on raw data; statistical analysis was performed on $(x + 0.5)^{1/2}$ transformed data. Trap counts for all Olson treatments were adjusted to the size of the Pherocon AM half trap (320.6 cm^2) prior to statistical analysis.

† Total cost of samples (n = 12) used for the Pherocon AM treatment was $6.00 (i.e., $0.50/trap) and, for each of the Olson treatments adjusted to the size of the Pherocon AM half trap, was $4.92 (i.e., $0.41/trap side).

western corn rootworm scouting program in Virginia. However, because the Olson trap has two functional sides and can be used for up to two trapping intervals, its cost per side is about $0.20, compared to about $0.50 per side for a Pherocon AM half trap. The combination of lower cost and greater numbers of western corn rootworm adults caught may make the 10.2 × 15.2 cm Olson yellow sticky trap a more efficient sampling tool for use in western corn rootworm scouting programs.

Acknowledgments

The authors thank M. G. Allen an D. L. Hatfield for their technical assistance in this project, and C. A. Laub and R. L. Pienkowski (Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg) for their critical reviews of an earlier draft of this manuscript. This research was supported in part by grants from the Virginia Pesticide Control Board and Virginia State Dairymen's Association.

References Cited

Chiang, H. C. and R. G. Flaskerd. 1965. Sampling methods of adult populations of the corn rootworms. Proc. N. Cent. Br. Entomol. Soc. Amer. 20: 67-68.

Foster, R. E., J. J. Tollefson and K. L. Steffey. 1982. Sequential sampling plans for adult corn rootworms (Coeloptera: Chrysomelidae). J. Econ. Entomol. 75: 791-793.

Heathcote, G. D. 1957. The optimum size of sticky aphid traps. Plant Pathol. 6: 104-107.

Hein, G. L. and J. J. Tollefson. 1984. Comparison of adult corn rootworm (Coleoptera: Chrysomelidae) trapping techniques as population estimators. Environ. Entomol. 13: 266-271.

1985. Use of the Pherocon AM trap as a scouting tool for predicting damage by corn rootworm (Coleoptera: Chrysomelidae) larvae. J. Econ. Entomol. 78: 200-203.

Karr, L. L. and J. J. Tollefson. 1987. Durability of the Pherocon AM trap for adult western and northern corn rootworm (Coleoptera: Chrysomelidae) sampling. J. Econ. Entomol. 80: 891-896.

Kirk, W. D. J. 1987. Effects of trap size and scent on catches of *Thrips imaginis* Bagnall (Thysanoptera: Thripidae). J. Aust. Entomol. Soc. 26: 299-302.

Parrella, M. P. and V. P. Jones. 1985. Yellow traps as monitoring tools for *Liriomyza trifolii* (Diptera: Agromyzidae) in chrysanthemum greenhouses. J. Econ. Entomol. 78: 53-56.

Pruess, K. P., J. F. Witkowski and E. S. Raun. 1974. Population suppression of western corn rootworm by adult control with ULC malathion. J. Econ. Entomol. 67: 651-655.

Roselle, R. M. 1977. An evaluation of the Nebraska method for predicting corn rootworm (*Diabrotica virgifera* LeConte) larval damage based on adult sampling. M. S. thesis, University of Nebraska, Lincoln.

Ruesink, W. G. 1980. Introduction to sampling theory, Pp. 61-78. *In* M. Kogan and D. C. Herzog (eds.), Sampling methods in soybean entomology. Springer-Verlag, New York.

Stamm, D. E., Z B Mayo, J. B. Campbell, J. F. Witkowski, L. W. Andersen and R. Kozub. 1985. Western corn rootworm (Coleoptera: Chrysomelidae) beetle counts as a means of making larval control recommendations in Nebraska. J. Econ. Entomol. 78: 794-798.

Staples, R. and W. B. Allington. 1959. The efficiency of sticky traps in sampling epidemic populations of the eriophyid mite *Aceria tulipae* (K.), vector of wheat streak mosaic virus. Ann. Entomol. Soc. Am. 52: 159-164.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw-Hill, New York.

Steffey, K. L. and J. J. Tollefson. 1982. Spatial dispersion patterns of northern and western corn rootworm adults in Iowa cornfields. Environ. Entomol. 11: 283-286.

Steffey, K. L., J. J. Tollefson and P. N. Hinz. 1982. Sampling plan for population estimation of northern and western corn rootworm adults in Iowa cornfields. Environ. Entomol. 11: 287-291.