PROJECT REPORT TO THE NEW YORK STATE IPM GRANTS PROGRAM

Title: Transect Sampling to Enhance Efficiency of Corn Rootworm Monitoring

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Abstract:
Crop monitoring for corn rootworm remains the best means to assess fields at risk from this pest if replanted to corn the following year. Improvements in sampling methodology have reduced the minimum sampling time required to make a management decision to about 20 minutes or less per field per visit to make a management decision. Many growers still find this time commitment a constraint to weekly scouting. The current sampling scheme involves covering most of the field following a "W" pattern. The goal of this project was to assess the feasibility of replacing this current sampling pattern with a simpler and less time-consuming transect (straight line) pattern. Our computer simulations demonstrate that treatment decisions based on transect sampling would have an acceptably low error rate (< 0.05) over a wide range of realistic rootworm densities and spatial dispersion patterns. Further research will be necessary to determine how likely rootworm populations are to fall within this range.

Introduction
Over the past decade, the western corn rootworm (CRW) has become established as the predominant insect pest of field corn in New York The more assertive nature and economically damaging capacity of western CRW, compared to the previously dominant northern CRW species, has increased grower awareness and concern of potential risks of CRW. Corn grown for silage is at particular risk from corn rootworm injury (Davis 1994). Western corn rootworm is also responsible for dramatic increases in overall soil insecticide use. A pesticide survey conducted in 1985 reported that 13.8% of the New York acreage received a soil insecticide (Specker et al 1986). By 1989 this figure had nearly doubled to 24.8% of the New York acreage being treated with a soil insecticide (Martiz Market Research, Inc.). In 1994, a PIAP survey of NYS producers found that 70.3% of grain corn acres and 17.3% of silage corn acres were routinely treated with an insecticide. Presumably, a large proportion of insecticide use was targeted towards CRW control (Partridge et al 1995).

This same PIAP survey found that producers utilized pest presence based on scouting as their criteria in making insecticide-use decisions on about 50% of NYS's grain (51.7%) and silage (50.3%) corn acres. In a 1998 survey of NYS field crop producers, Waldron (unpublished) found that 77% of the 1074 growers polled monitored their field corn. Forty-two percent of those monitoring did so 2-3 times per season, 21% - more than 4 times per season, and 8% did so weekly. Nearly 60% of those surveyed expressed concern (26% low, 20% moderate, and 13% high level of concern) for the amount of time required to monitor crops for pest problems. Clearly, growers are interested in monitoring as a means to enhance pest management decisions but feel time required to do so is an element of concern.

Prior to 1991, CRW monitoring procedures required an assessment of CRW beetle numbers on five plants in each of eleven areas within a field. This activity could take as much as ninety minutes per field (Sawyer, 1985). To simplify this protocol and time commitment, Shields et al (1991) developed a sequential CRW sampling method enabling producers to assess a twenty acre or smaller field for CRW in twenty minutes or less. This sampling method has helped increase adoption of IPM practices to optimize management of CRW.

It may be possible to reduce sampling time even further while maintaining the current level of accuracy in characterizing adult CRW densities as above or below threshold. In the currently used sequential sampling scheme the sampler counts the beetles on a single stalk and then moves on to a new site in the field (Shields et al. 1991). Sawyer (1985) estimated that walking between sites took an average of 0.75 minutes. Thus, a substantial proportion of the time spent in the field is taken by walking between sites. Within a cornfield more time is taken to cross a row then to walk the same distance within a row. The time taken in travel between sites is largely a function of the absolute distance and the number of rows that are crossed.

Taking each sample in a different location is necessary for accurate data if pests are highly aggregated or clumped. Adult corn rootworm distributions vary widely in their level of aggregation (Shields et al. 1991) so a simpler sampling scheme involving less walking may be possible. Specifically, if adults in a given field were randomly distributed then "the presence of one individual does not influence the distribution of another" (Southwood 1978). A range of factors can influence how adult CRW are distributed in the field including relative maturity of plants, planting depth, soil type, soil moisture and fertility (Davis and Coleman 1997, Allee 1998). Data from several studies indicates that a significant proportion of fields have rootworm populations that were randomly or even more widely (nearing uniformity) dispersed (Sawyer 1985; Steffey and Tollefson 1982). This implies that it may be possible to obtain accurate rootworm population estimates by sampling closely spaced stalks in a row or "transect". The transect sampling method would minimize travel time between sites. The goal of our project is to determine how well the transect method compares to the current systematic method.

Our specific original objectives were: 1) to determine the range of conditions across which transect sampling provides acceptably accurate results with computer simulation models and, 2) to test the accuracy (in terms of decision-making) and efficiency (in terms of time saved) of transect sampling in the field. Due to limitations in the currently available and to the paucity of data available on CRW spatial distribution, it was necessary to construct a much more complex computer model and thus it was not possible to test the new model within the one year time frame. The remainder of this report provides details of the construction of the computer model, the results of the simulation, a discussion of their implications, and an outline for further research in this area.

Construction of the utilization of the simulation model

Simulating a corn field and a CRW population: The simulation software performs comparisons of three different sampling methods on a simulated corn field over a range of possible density and dispersion coefficients (see appendix 1). The field can be generated with variable grid sizes corresponding to various dispersion conditions. Densities are allocated per grid according to the negative binomial distribution and inside the grid the counts are allocated according to the Poisson distribution. To ensure that the complete range of possible spatial dispersions were investigated, one completely uniform dispersion was included in each set with k=0 and no variance.

Sampling the simulated CRW populations: Each simulated CRW population is “sampled” with three sampling schemes random, systematic and transect sampling. To simulate transect sampling one row is chosen randomly and every 10th plant in that row is sampled. The simulation of systematic emulates the zig-zagging motion of the “W” pattern using a pre-calculated motion matrix (see appendix 1). Random sampling is simulated by evaluating plants randomly chosen from the entire field.

Evaluating sampling schemes: Based on the CRW numbers generated from each sampling scheme a treatment decision is reached using the Cornell guidelines (Shields et al. 1991) with an action threshold of one beetle per stalk. The decisions made by the methods are compared to the decision based on the actual density of the field as well as between each other. For each set of parameters (density, grid size, k-value) six comparisons are made (each method vs. the actual known density and each method with each other) and three values are generated for each comparison (total error, type I error, type II error). For comparisons of the sampling methods with the actual density, type I errors represent decisions to treat when CRW density is less then one beetle per stalk and type II errors represent decisions not to treat when densities are greater or equal to one. For comparisons between sampling methods, type I errors represent cases where the first method in the pair being compared returns a decision to treat and the second returns a decision not to treat. Type II errors represent the opposite case.

If the program is set to run multiple times, the coefficients from each run are collected and the mean and the standard deviation are calculated and printed. If the number runs is set to 1, the mean represents the coefficient from the run and the standard deviation is 0. During the first run for each grid size the combinations of density and k on which the particular made an incorrect decision are output to corresponding files. For this project each set of parameters was run 30 times. Results for runs of each grid size (averaging across density and k values) are output to a file (see table 1).

Results and Discussion

Although several studies have addressed spatial dispersion of CRW adults in corn all of these studies measured dispersion on the basis of individual plants. While this provides useful information it does not address dispersion patterns where CRW adults are aggregated in larger spatial patterns. Many other herbivores have been shown to aggregate in clumps or hotspots that encompass groups of plants of various sizes. In the absence of this data we simulated aggregations at several scales to determine the impact of this higher scale aggregation on the accuracy of the three sampling methods. One of the most important results of our study is that the scale of aggregation has a major impact on the relative accuracy of the three sampling methods.

The results of the computer simulations demonstrate that all three sampling schemes are very accurate (< 3% error) if aggregations are on the level of a single plant (Table 1a). For all larger-scale aggregations, systematic sampling maintains an accuracy of approximately 95% while the accuracy of random and transect sampling drops to approximately 90% (Table 1 b-f). Transect sampling provides adequate accuracy if beetles are aggregated only at the level of a single plant. Furthermore, even at higher levels of aggregation there will be a range of k values (lower values corresponding to low levels of aggregation) within which transect sampling produces an error rate of 5% or less.

A somewhat unexpected outcome of the simulations was the extent to which systematic sampling outperformed random sampling (Table 1). True random sampling requires use of a random number generator to produce coordinates and it is usually much more time consuming than systematic sampling because it precludes plotting an optimal path through the field. For instance one randomly chosen sample might be across the field from the previous sample. Sophisticated software can generate coordinates and plot an optimal path but there are complications for sequential sampling programs because the total number of samples is not known *a priori*. The simulations indicate that not only is systematic sampling more efficient than random sampling but it is also more accurate for populations which are thought to be aggregated but where there is no prior knowledge of the pattern of aggregation.

Systematic sampling represents an improvement in efficiency over random sampling and it would appear that transect sampling has the potential to increase efficiency even further. The current simulations clearly demonstrate this potential. The next steps in the process of determining if transect sampling can be utilized for CRW are: 1) further simulations to determine the range of k values over which transect sampling provides acceptably accurate data, 2) intensive field monitoring of CRW spatial distributions to determine how likely they are to be distributed in a way that will allow accurate transect sampling, and, 3) comparison sampling with the three sampling methods in the same fields to "ground proof" the results of the model. If these further steps confirm that transect sampling can improve sampling efficiency while maintaining an acceptable level of accuracy then the process of integrating transect sampling into the CRW IPM program can be initiated.

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Table 1. Results of the simulation model.

A. Grid size 0001 x 0001

		Total error	Type I error	Type II error
Transect sampling	mean	0.036983	0.011445	0.025538
	std dev	0.002815	0.001675	0.002069
Systematic sampling	mean	0.035769	0.010913	0.024856
	std dev	0.004099	0.002853	0.005822
Random sampling	mean	0.036369	0.010831	0.025538
	std dev	0.002531	0.001329	0.002069
Transect vs systematic sampling	mean	0.050244	0.025047	0.025197
	std dev	0.003317	0.004760	0.004241
Systematic vs random sampling	mean	0.049985	0.025257	0.024728
	std dev	0.003138	0.004139	0.004597
Transect vs random sampling	mean	0.050015	0.025197	0.024818
	std dev	0.003751	0.002402	0.002140

B. Grid size 0002 x 0004

		Total error	Type I error	Type II error
Transect sampling	mean	0.105662	0.033933	0.071729
	std dev	0.020559	0.023518	0.032577
Systematic sampling	mean	0.047972	0.037035	0.010937
	std dev	0.002073	0.001641	0.000955
Random sampling	mean	0.085329	0.013600	0.071729
	std dev	0.031841	0.001280	0.032577
Transect vs systematic sampling	mean	0.118673	0.027390	0.091283
	std dev	0.027227	0.017086	0.038552
Systematic vs random sampling	mean	0.064776	0.051586	0.013190
	std dev	0.002762	0.002963	0.000956
Transect vs random sampling	mean	0.110264	0.042383	0.067880
	std dev	0.019707	0.023962	0.030270

C. Grid size 0003 x 0012

		Total error	Type I error	Type II error
Transect sampling	mean	0.100275	0.032589	0.067687
	std dev	0.023034	0.024950	0.036899
Systematic sampling	mean	0.050501	0.039247	0.011254
	std dev	0.002404	0.001991	0.000903
Random sampling	mean	0.082576	0.014890	0.067687
	std dev	0.036363	0.001646	0.036899
Transect vs systematic sampling	mean	0.114892	0.025901	0.088992
	std dev	0.031248	0.017447	0.043539
Systematic vs random sampling	mean	0.069293	0.055083	0.014211
	std dev	0.002684	0.002667	0.001017
Transect vs random sampling	mean	0.107111	0.042446	0.064665
	std dev	0.019108	0.024936	0.034197

D. Grid size 0004 x 0016

		Total error	Type I error	Type II error
Transect sampling	mean	0.101462	0.032709	0.068753
	std dev	0.021895	0.024770	0.038166
Systematic sampling	mean	0.051095	0.039489	0.011606
	std dev	0.002544	0.001829	0.001178
Random sampling	mean	0.084158	0.015405	0.068753
	std dev	0.037160	0.001404	0.038166
Transect vs systematic sampling	mean	0.115795	0.025934	0.089862
	std dev	0.033133	0.017226	0.045848
Systematic vs random sampling	mean	0.070409	0.055519	0.014890
	std dev	0.003112	0.003290	0.001073
Transect vs random sampling	mean	0.107569	0.042135	0.065434
	std dev	0.019528	0.024295	0.035502

E. Grid size 0006 x 0024

		Total error	Type I error	Type II error
Transect sampling	mean	0.105856	0.034591	0.071265
	std dev	0.024841	0.024490	0.042591
Systematic sampling	mean	0.048670	0.035439	0.013231
	std dev	0.002940	0.002409	0.001232
Random sampling	mean	0.086897	0.015632	0.071265
	std dev	0.041624	0.001755	0.042591
Transect vs systematic sampling	mean	0.116810	0.028964	0.087846
	std dev	0.035154	0.017550	0.048679
Systematic vs random sampling	mean	0.066866	0.050160	0.016706
	std dev	0.003301	0.003258	0.001363
Transect vs random sampling	mean	0.112743	0.043657	0.069086
	std dev	0.022451	0.024007	0.039930

F. Grid size 0008 x 0032

		Total error	Type I error	Type II error
Transect sampling	mean	0.107310	0.030047	0.077263
	std dev	0.026307	0.018151	0.038528
Systematic sampling	mean	0.045711	0.032436	0.013275
	std dev	0.002559	0.002206	0.001437
Random sampling	mean	0.092366	0.015102	0.077263
	std dev	0.037469	0.001964	0.038528
Transect vs systematic sampling	mean	0.119690	0.026656	0.093034
	std dev	0.034020	0.012946	0.043008
Systematic vs random sampling	mean	0.064864	0.047732	0.017132
	std dev	0.002728	0.003143	0.001667
Transect vs random sampling	mean	0.112252	0.038237	0.074015
	std dev	0.023229	0.018191	0.035427

Appendix 1. Model Parameters

The following parameters stand for width and length of the field (in meters), number of rows, number of stalks per row, ranges of density (CRW per stalk) and dispersion (k) coefficients, sizes of the grid, and number of program runs respectively. The values are designed to emulate a square 10 acre field with a plant density of approximately 28,000 plants per acre. Note that one of the six grid sizes is represented below. Grid sizes (row x plants-in-row) include (1x1, 2x4, 3x12, 4x16, 6x24, 8x32).

Parameters:
WIDTH=204.4
LENGTH=204.4
ROWS=264
COLUMNS=1056
DENSITY_MIN=0.0
DENSITY_MAX=5.0
DENSITY_STEP=0.1
K_MIN=0.0
K_MAX=6.0
K_STEP=0.1
ROWS_PER_GRID=1
COLUMNS_PER_GRID=1
RUNS=30

A separate file contains 54 pre-calculated motion coordinates for the systematic (W) sampling method. These pre-calculated parameters start at a corner of the field and traverse it twice from one side to the other on an angle of approximately 22°. Individual plants to sample are specified by row and plant number within the row.

Systematic matrix (row,plant)
1,1
5,82
10,163
15,244
20,325
25,406
30,487
35,568
40,649

The software utilizes mathematical functions from Cephes math library. Software was designed and constructed by Vladimir Zbarskiy djtexho@cryogen.com.