A Binomial Sequential Sampling Plan Using a Composite Threshold for Caterpillar Management in Fresh Market Collard[1]

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ABSTRACT   Two sampling methods for caterpillars in collard (*Brassica oleracea* (L.) var. *acephala* DC.) were compared for precision and time efficiency, and a composite economic threshold (ET) was established for caterpillar management. In addition, a presence/absence sequential sampling plan, based on the binomial distribution, was developed. Differences between population estimates for diamondback moth larvae, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) and cabbage looper larvae, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), were not significant whether one plant was sampled at 100 locations or five plants were sampled at 20 locations. Time needed to sample fields was significantly faster when five plants were sampled in 20 locations compared with one plant in 100 locations. A composite threshold of 0.1 cabbage looper equivalent per plant was established for collard. The presence/absence sequential sampling plan was developed using a lower limit of 10% infested plants and an upper limit of 20%. Simulated scouting using the sequential method was performed on 150 field records from three farms, and the decisions compared with those of a conventional fixed-number (100) sampling method. The sequential sampling method agreed with the more intensive method 90% of the time (90.1% ± 4.4%). The sequential method required only 24 samples (23.8 ± 0.8) for a decision, which was a reduction of more than 75% (76.3 ± 0.3%) over the conventional, fixed-number method.

KEY WORDS   Binomial sequential sampling, *Brassica oleracea*, composite threshold, *Plutella xylostella, Trichoplusia ni*

Fresh market collard, *Brassica oleracea* (L.) var. *acephala* DC., is the most economically important vegetable crop in Lexington County, South Carolina, where it comprises approximately one half of the 1,620 hectares of brassica crops grown annually and most of the 1,012 hectares of collard grown in South Carolina in 2000 (Anonymous, 2001). Lepidopteran pests, mainly the diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), and the cabbage looper

(CL), *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), are major constraints to collard production in South Carolina.

Pest-management strategies for lepidopteran pests of cabbage (Greene 1972, Shepard 1973, Chalfant et al. 1979, Shelton et al. 1982, Maltais et al. 1998) and other brassica crops (Stewart & Sears 1988, Maltais et al. 1994) are used in other areas of North America, but strategies for collard integrated pest management (IPM) are lacking. Before 1997, damage thresholds were not available for proper timing of pesticide applications to collard. In response to widespread DBM control failures in 1994, a program to study the DBM/collard pest/crop system was initiated in 1996. Khan (1998) identified resistance to the cryIAc and cryIC endotoxins of *Bacillus thuringiensis* Berliner (Bt) in DBM collected from collard in Lexington County. Growers were informed of these results and encouraged to begin a scouting program. Such a program could potentially reduce the number of pesticide applications and slow the development of pesticide resistance. Scouting was initiated in 1997 using a threshold developed for cabbage of 0.1 cabbage looper equivalents (CLE) per plant (Greene 1972). A major criticism of the pest-management program by producers was that field scouting using a fixed number of plants to make a decision was too time-consuming. In addition, they wanted an economic threshold (ET) specific for collard.

Composite thresholds that group insects into feeding "guilds" that cause similar feeding damage and do not require enumeration of the various species substantially decrease sampling time (Cartwright et al. 1987). Composite thresholds based on the percentage of damaged plants that are infested with live larvae, rather than counts of larvae, further reduce sampling time. This relieves the field scout of the tedium associated with counting larvae (Kirby & Slosser 1984, Morisak et al. 1984). Shelton et al. (1982) coined the term CLE based on foliage consumption rates reported by Harcourt et al. (1955). Other composite thresholds based on the amount of feeding damage and percent of plants infested by any caterpillar have been formulated for use in managing caterpillars in brassica crops in various parts of North America (Chalfant et al. 1979, Workman et al. 1980, Kirby & Slosser 1984, Morisak et al. 1984, Sears et al. 1985, Cartwright et al. 1987, Stewart & Sears 1988, Maltais et al. 1998, Hines & Hutchinson 2001).

Commercial collard fields were chosen for this study because a workable plan with commercial application was one of the major goals of our project. Shelton & Trumble (1991) stated that, "one of the more common errors in the literature is the collection of dispersion information from untreated fields and the subsequent development of sampling plans for fields that receive pesticide applications." Trumble (1994) stated, "Finally, the available literature is filled with papers describing sampling plans that will never be used commercially; failure to validate a proposed sampling plan in large-scale commercial operations is probably the single most important reason that such plans are not adopted."

Sequential sampling, developed by Wald (1943), is a means of quickly classifying populations into broad categories (Waters 1955, Shepard & Ferrer 1990). Wald's method is known as the "sequential probability ratio test"; plans using this method have been collected in a bibliography by Fowler & Lynch (1987a) and the methodology reviewed by Fowler & Lynch (1987b), Nyrop & Binns (1991), and Legg & Chen (2000), among others. Some workers have shown an 80% or greater reduction in the number of samples compared with fixed-number sampling (Shepard et al. 1986, Fowler & Lynch 1987b). Sequential sampling can reduce the time

spent sampling by 50% or more (Binns 1994), and it does not require exact population parameters be estimated (Waters 1955). Although this technique does not estimate the mean density of a pest population, the number of samples required to make a decision changes in relation to the mean density (Pedigo & Zeiss 1996). Three factors required to devise a sequential sampling scheme are: 1) the mathematical distribution of the insect, 2) the economic threshold (or other information pertaining to class limits), and 3) the level of risk of making a wrong classification (Waters 1955, Shepard & Ferrer 1990, Pedigo & Zeiss 1996).

Several techniques can reduce sampling time. Presence/absence sampling reduces the need for tedious counting of insect larvae, thereby reducing sampling time. Presence/absence sampling can be adapted easily to sequential sampling, as it fits the binomial distribution (Kuno 1991). A composite threshold is based on the proportion of infested plants (possibly by multiple species) and does not require species determination. Using such thresholds substantially reduced sampling time and produced cabbage of acceptable market quality while reducing insecticide applications (Kirby & Slosser 1984, Morisak et al. 1984).

Our study was undertaken to 1) compare the time efficiency and precision of two conventional methods (CM) that involved using a fixed number of samples, 2) determine a composite, population-based ET and, 3) develop a presence/absence sequential sampling method (SSM) to determine whether treatment is necessary for the major caterpillar complex on collard. The conventional method used by growers called for a fixed sample size of 100. The proposed method was developed to determine whether a binomial sequential sample plan that uses a composite threshold would be as precise and more efficient than the growers' method. Although the fixed point sampling method using 100 sample points, reduced the average number of pesticide applications from 14 to less than 6 (J. P. Smith, unpublished data), the growers' major concern was reducing the scouting time needed to make a decision while maintaining confidence in the scouting information and decisions reached.

Materials and Methods

To determine the relationship between infestation and damage levels, three commercial collard fields of similar shape, approximately 4.0 hectares each, were chosen randomly in the summer of 1999 on three Lexington County, South Carolina, farms. The fields were divided into four areas of approximately equal size, and a "W"-shaped sampling route was walked by the scout in each field on each scouting event. One leg of the "W" was entirely in each of the four areas.

Sample sites consisted of an individual plant chosen randomly along the sampling path; each area had 25 sample sites. Another sampling plan was developed that involved randomly choosing plants at five sample sites along the sampling route in each area. Using this plan, the plant chosen plus the two adjacent plants on each side of it in the row were sampled for five plants per location. Thus, there were 25 sample sites per area. Each sampling plan examined 100 samples per field. Fields were sampled every 3 to 5 days beginning about 2 weeks after transplanting and continuing until harvest; the species and numbers of caterpillars found were recorded. The amount of time spent sampling each field using each of the sampling schemes was recorded. Both sampling methods were carried out by the same person.

Previous observations had shown that the harvested portion of fresh market collard in Lexington County consists of the top 19 internodes of the collard plant (J. P. Smith, unpublished data). Immediately before harvest, this portion of the randomly chosen plants that were sampled for insects was assessed for cumulative caterpillar feeding damage. A six-level rating scale to evaluate caterpillar-feeding damage on collard was devised (Table 1).

Differences between the estimates of the population means for the caterpillar species determined by the two sampling methods in the same fields were compared using paired t tests ($P = 0.05$). The CLE/plant counts were transformed using a square root transformation to reduce the effects of the many small numbers and zeroes encountered when low caterpillar population estimates were converted to per-plant values. Differences in sampling times between the two methods were analyzed in the same way, although no transformation was used. Normality of these sets of data was determined using the "W" statistic (Christensen 1996).

A feeding equivalency of 1 CL = 1.5 imported cabbageworm (ICW) = 5 DBM (Maltais et al. 1998) was used to convert the caterpillar numbers to CLE. Linear regression was used to determine the relationship between CLE/plant and feeding damage. This relationship was used to establish an ET. Linear regression was used also to determine the relationship between the number of CLE/plant and percent-infested plants.

A sampling model was developed based on the binomial distribution. The sampling scheme included 2 classes of plants: infested or uninfested. Plants with a damage rating of 2.0 or greater (Table 1), along with one or more live larva(e) were recorded as infested. Plants with a damage rating less than 2 with live larvae, undamaged, uninfested plants, or plants damaged at any level without live larvae were recorded as uninfested. Data from the three fields were combined, an analysis of variance performed, and the treatment means were compared using Fisher's LSD test (Minitab 1998). The relationship between damage levels and percent infestation was examined using linear regression.

The CLE-based ET, determined as described previously, was used to develop a SSM using equations for the binomial model reported by Waters (1955). The mathematical calculations necessary to derive the decision-line graph for the sequential model and the sequential table were performed using a computer program developed by Shepard & Grothusen (1984).

Ten fields from each of three farms were selected randomly to test the sequential plan. The time required to scout these fields using a CM and using the SSM were recorded. Field scouts were instructed that of the first four sets of five-plant samples, one should come from each of four sections of the fields when the field was divided into four approximately equal areas. If a decision was not reached after these first four sets of samples, the pattern should be repeated with the next four sets of samples until a decision could be made. This method ensured that the entire field was represented in the sampling. Care was taken to ensure that edges and interiors of the fields were sampled equally. The times required to scout the fields using both techniques were compared using paired t tests.

Fifty scouting records were chosen randomly from each of three farms. The numbers of plants examined by the scout (which was always 100 using the CM) and the decision from the assessment (based on the threshold of 0.1 CLE/plant) (Greene 1972) for each of these records were compared with sample numbers and

Table 1. Six-level damage rating scheme for caterpillar feeding on collard foliage.

Damage level	Definition of damage
0	No damage
1	Damage to some leaves $\leq$2 small holes[a] and/or 1 large hole[b] or more damage (holes) but confined to one leaf that could be easily trimmed.
2	Damage to some leaves 3 to 5 small holes and/or 2 large holes.
3	Damage to some leaves 6 to 8 small holes and/or 3 large holes.
4	Damage to some leaves 9 to 11 small holes and/or 4 large holes.
5	Damage to some leaves $\geq$15 holes of any combination.

[a]A small hole was defined as <7 mm in diameter.
[b]A large hole was $\geq$7 mm (7 mm = diameter of a pencil eraser).
Using this scale, 0 and 1 were always marketable, 2 was marketable although some trimming could be necessary, 3 could be marketed with trimming, and 4 and 5 are unmarketable.

decisions reached using the sequential sampling table. One of two scouting patterns was assigned randomly to each of the field records that defined the sample order to simulate scouting of the whole field. The mean caterpillar population estimates (as CLE/plant) were recorded for each decision category, and the decisions in each category were examined with respect to the population-based ET of 0.1 CLE/plant.

Results and Discussion

There were no significant differences between mean population estimates of DBM and CL obtained with the five-plant and the single plant sample units ($P > 0.05$; Table 2). The five-plant method was significantly ($P < 0.05$) faster (difference = 0.94 h ± 0.06 hr). Because of the substantial savings in time without loss of precision, the sequential sampling model was developed using five plants as the sample unit. Theunissen & den Ouden (1983) found no significant differences in population estimates for caterpillars in Brussels sprouts using 100 single plants versus 20 groups of five plants each for two sampling dates.

The mean cumulative damage rating correlated well with the square root-transformed mean estimates of CLE per plant (Fig. 1). The regression line in Fig. 1 shows that a damage rating of 1.0 corresponds with 0.103 CLE; this agrees with the 0.1 CLE threshold established by Greene (1972). Maltais et al. (1998) found that insecticide applications according to this threshold resulted in a percentage of marketable cabbage heads comparable to weekly insecticide applications but at less cost. Shepard (1973) used this threshold (0.l larvae/plant) to develop a sequential sampling scheme for CL in cabbage in central Florida. Higher composite thresholds (0.3 larvae/plant) have been proposed for caterpillar management in cabbage in Texas (Cartwright et al. 1987), but these researchers did not relate CLE to actual caterpillar populations.

Table 2. Mean number of DBM or CL larvae per collard plant as determined by assessing five plants in 20 locations and one plant in 100 locations in three collard fields (n is number of population estimates on each farm), Lexington County, South Carolina, 1999.

Farm/species	Larvae/ plant 20 stops	Larvae/ plant 100 stops	Mean difference	t[a]	P value
FarmB[b]/DBM	0.008	0.014	0.006	−1.50	0.208
FarmB/CL	0.014	0.008	0.006	0.69	0.529
FarmSH[c]/DBM	0.049	0.064	0.015	−0.57	0.591
FarmSH/CL	0.195	0.302	0.107	−0.61	0.571
FarmSP[d]/DBM	0.343	0.443	0.100	−0.43	0.680
FarmSP/CL	0.256	0.321	0.066	−0.55	0.601

[a]Paired *t*-tests compared differences in larvae/plant for each pair of fields to 0 (df = 1).
[b]n = 5.
[c]n = 7.
[d]n = 7.

The percentage of infested plants was highly correlated with the square root-transformed number of CLE per plant (Fig. 2). This relationship is essential for the development of a presence/absence-sampling scheme (Shepard & Ferrer 1990). Waters (1955) stated that "considerable time and expense can be saved if arbitrary limits are set for just two classes: 'needing control' and 'not needing control'." These class limits, of course, must be based on a fundamental knowledge of the insect and crop conditions. The regression of damage rating on percent-infestation predicts that a 20% infestation level would result in a damage rating of 1.64 (Fig. 3) and 0.19 CLE per plant (Fig. 1). This is less than damage level 2.0, which would not be acceptable without removing some of the outer leaves, and can be used as the upper limit of damage for constructing the binomial SSM (Waters 1955). A 10% level of infestation corresponds with 0.06 CLE per plant (Fig. 2) and has a damage level of 1.18 (Fig. 3). This is less than the ET of 0.1 CLE and can be used as the lower limit of the SSM. The actual ET of 0.1 CLE equals a 13.7% level of infestation, and this value is within the upper and lower class limits.

Percentage-based thresholds of 10% infestation by any larvae (Hines & Hutchinson 2001) and 30–70% infestation depending on growth stage (Morisak et al. 1984) have been proposed for managing caterpillars on cabbage. Data from the Lexington County studies (Fig. 3) indicate that sustained infestations near 20% in collard would result in reduced marketability. Morisak et al. (1984) noted that as CL population density increased in late season, damage also increased, resulting in a lower percentage of marketable heads. Their high thresholds (30–70%) may have underestimated the damage from the larger, more voracious feeding CL compared with the other pests identified in their study.

Hines & Hutchinson (2001) reported that the CL was the most destructive and difficult to control pest of cabbage in Minnesota, and a threshold based solely on the percentage of CL resulted in a reduced number of insecticide applications while producing a high percentage of marketable heads. Furthermore, they stated that although the CL may be the most damaging pest in a certain region, eco-
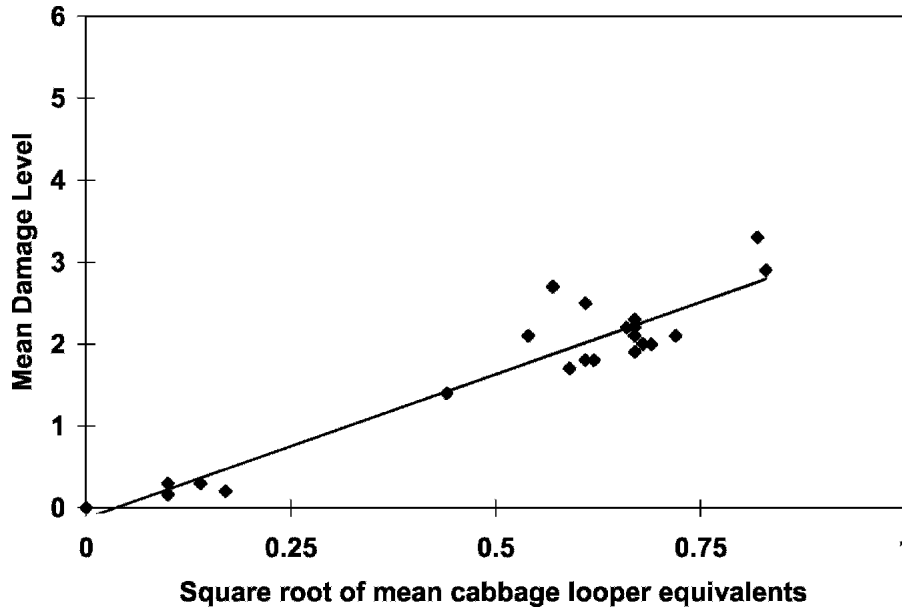
Fig. 1. Relationship of the mean damage rating and the mean number of cabbage looper equivalents per plant (square root transformation) in three Lexington county collard fields. Line drawn represents the linear regression $y = 3.52x - 0.13$, $R^2 = 0.91$, df $= 1, 23$; $P < 0.001$.

nomically significant infestations of other pests may develop in other geographic regions or other seasons, so multispecies thresholds based on concepts such as the CLE must be available. These observations support the adoption of the CLE concept for defining caterpillar infestation in collard, because caterpillar infestations in collard in Lexington County are comprised mainly of both CL and DBM. Obviously, thresholds based on the percentage of infested plants would avoid the necessity of counting caterpillars and would result in much less scouting time (Shelton et al. 1983, Morisak et al. 1984, Sears et al. 1985).

Our results support the 10–20% infestation range for the class limits for the SSM for caterpillar management in collard and agree with the ET of 0.1 CLE per plant that is widely used for caterpillar management in other brassica crops (Greene 1972, Maltais et al. 1998). Other workers (Morisak et al. 1984, Cartwright et al. 1987, Maltais et al. 1998, Hines & Hutchinson 2001) have shown that marketable brassica crops can be produced using thresholds between 10% and 30%.

Scouting collard using a percent-infestation threshold calls for a decision based on the presence or absence of caterpillars. This conforms to the definition of the binomial model, since a plant can be classed in only two ways—infested or not infested (Waters 1955, Kuno 1991). The infestation level of 10% was used as the lower limit and an infestation level of 20% as the upper limit in the equations for the binomial model illustrated and discussed in Waters (1955) to develop the decision lines for the SSM (Fig. 4). Although the presence/absence technique
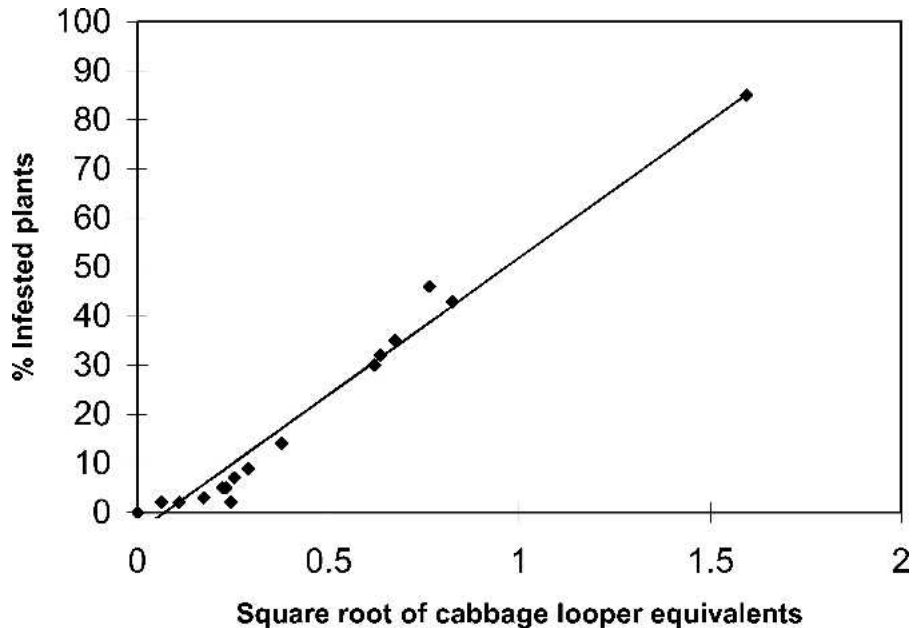
Fig. 2. Relationship of percentage of infested plants to number of cabbage looper equivalents per plant (square root transformation). Line drawn represents the linear regression $y = 55.87x - 3.99$, $R^2 = 0.98$, df = 1, 17; $P < 0.001$.

reduced the need to count and identify larvae, the scouts and growers wanted some way to identify the species composition of the infestations. A tabular form was developed which included space to record the species that were encountered in each field.

Although a treat decision could be reached after only four plants were examined, a don't-treat decision required that a minimum of 18 plants be examined. Field scouts were instructed to choose a minimum of one group of five plants in each of the four areas of each field. This allowed adequate coverage of the fields and gave an equal opportunity of either decision being reached. Also, this aided in identifying localized infestations. A maximum of 45 samples could be taken using this SSM. If a decision could not be reached after 45 samples, scouts were instructed to resample the field after 2 days. The computer program of Shepard & Grothusen (1984) that derived the points used in constructing the decision lines required that a maximum number of samples be entered for the model. The CM to which the SSM was compared used a maximum of 100 samples, so this number also was used in the computer program. Although 100 samples could be examined using the SSM, in only 4 cases out of the 136 'treat' or 'don't treat' decisions when simulated scouting was performed using the CM field records did the number of samples necessary to make a decision exceed 35. A decision to treat or not treat still could not be made in 13 of 14 'resample after 2 days' cases after carrying the simulation through 100 samples. Therefore, for simplicity and ease of designing
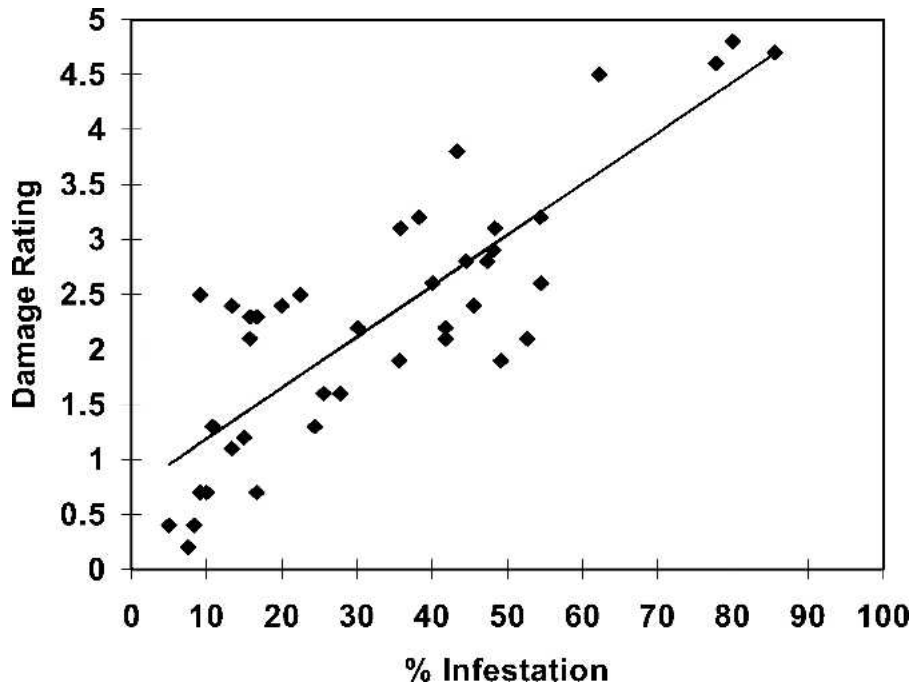
Fig. 3. Relationship of the damage rating and the percentage infestation in all treatments in two collard caterpillar economic threshold experiments in Lexington County, South Carolina. Line drawn represents the linear regression y = 0.046x + 0.72, R^2 = 0.70, df = 1, 38; P = 0.001.

the tabular form for field use, a maximum number of 45 samples was used on the form. This was almost twice the average number of samples (23.8 ± 0.8) needed to make a decision in the 150 simulations.

Although it was apparent that the SSM was faster as a result of the fewer number of samples required, a comparison of scouting times of the 10 randomly selected fields from each of the three farms using the presence/absence SSM and the CM was done to demonstrate and quantify the difference in time. The mean time per field required to scout thirty fields using the presence/absence SSM (0.61 ± 0.04 h.) was significantly less (P < 0.05) than the mean time required to scout the same fields using the CM (2.16 ± 0.14 hr).

The decision data from the three farms combined show that the decision reached using the SSM agreed with the CM decision 90% of the time (90.1 ± 4.4) and required only a mean of approximately 24 samples (23.8 ± 0.8) for a decision instead of the 100 samples required by the CM (Table 3). Shepard (1973) showed similar time saving for a sequential sampling scheme for CL management in cabbage.

Categories of possible outcomes of the decision comparisons were: 1) agree, 2) agree (where the CM resulted in recommendation for no treatment and the SSM resulted in recommendation for resampling after 2 days), 3) disagree (where the
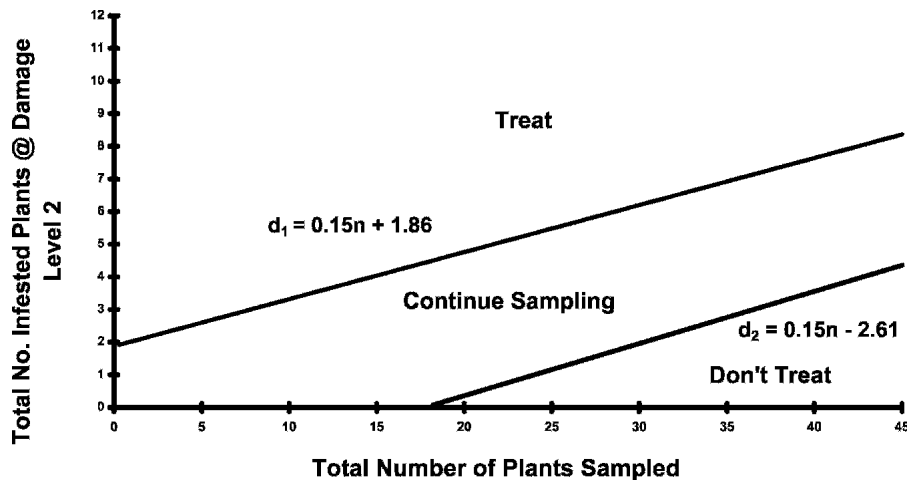
Fig. 4. Decision lines and equations for presence/absence sequential sampling plan using the binomial model. The lower limit of caterpillar infestation = 0.1, the upper limit = 0.2, the chance of calling a nondamaging population damaging (α) = 0.2, and the chance of calling a damaging population nondamaging (β) = 0.1.

CM resulted in recommendation for no treatment and the SSM did not), 4) disagree (where the CM resulted in recommendation for no treatment and the SSM did), and 5) disagree (where the CM resulted in recommendation for treatment and the SSM resulted in recommendation for resampling after 2 days). In only 14 of 150 decisions (9.3%) did the SSM results disagree with the CM results. The SSM resulted in recommendation for treatment in 10 cases where the CM results did not. The SSM resulted in a failure to recommend treatment in only one situation where the CM result recommended treatment. There were three cases in which the CM resulted in a recommendation for treatment and the SSM results recommended resampling after 2 days. The SSM results disagreed with the CM results 9 of 50 times (18%) on Farm RR; this was the highest level of disagreement. On this farm, there were 14 cases where the CM results recommended don't treat and the SSM results recommended resampling after 2 days. This also was the highest number of resampling/don't treat decisions.

There were two disagreements where the mean CLE/plant was low, but the SSM recommended treatment. In these cases, the situations were examined, and it was determined that the infestation was a highly dispersed DBM population. The predominance of DBM resulted in a low CLE/plant but the highly dispersed nature of the infestation resulted in a high number of infested plants hence the treatment decision by the SSM. Such cases are expected when using a presence/absence system and/or a composite threshold.

As other authors have reported (Waters 1955, Shepard et al. 1986), decisions were reached with the least number of samples when the populations were either very low or very high. When the populations in this study were near the threshold

Table 3. Comparison of decision outcomes, sample numbers, and percentage reduction in sampling numbers between presence/absence sequential sampling (seq.) and conventional fixed-point sampling (conv.) for caterpillar management in collard in Lexington County, South Carolina, 1999.

Decision source (50 records/farm)	No. samples conv.	Mean ± SEM no. samples seq.	% Reduction in sample number	Decision agrees (50 decisions)	Decision disagrees (50 decisions)	% agreement
Farm RR	100	23.9 ± 1.4	76	41	9	82
Farm OF	100	23.2 ± 1.4	77	48	2	96
Farm CF	100	24.4 ± 1.4	76	47	3	94
Three farms combined (mean ± SEM)	100 ± 0	23.8 ± 0.8	76.3 ± 0.3	45.3 ± 2.2	4.7 ± 2.2	90.1 ± 4.4

of 0.1 CLE/plant, more samples were required. Ferrer & Shepard (1987) reported that a sequential sampling plan for Malaysian black bug (MBB), *Scotinophora coarctata* (F.) (Heteroptera: Pentatomidae), in rice agreed with the intensive plan 95% of the time, but tended to remain in the "continue sampling" area of the sequential table when the MBB populations were near the threshold.

The fact that the upper and lower limits for this SSM in collard is based on percent infested plants instead of actual caterpillar densities expressed as CLE/plant tends to overemphasize the importance of DBM populations. Morisak et al. (1984) reported that a 30%-infested plant threshold for caterpillar management on cabbage in Ohio protected the cabbage well in the early season, but, later in the season when the CL became more prevalent, this threshold did not protect the cabbage from insect damage. The high percent-infestation threshold worked well in early season when DBM was prevalent and caterpillar numbers were less, but this high threshold underemphasized the importance of CL populations. Hines & Hutchinson (2001) reported that the CL was the most damaging insect on cabbage in Minnesota and that a threshold of 10%-infested plants with any caterpillar provided adequate protection for cabbage there. This low threshold was better suited to the more damaging feeding habits of the CL than the less damaging feeding habits of the DBM. Unlike cabbage, cosmetic standards for the foliage of leafy greens are very high, and this model was designed to be conservative to prevent undue losses by classifying damaging caterpillar populations as non-damaging.

These data indicate that this SSM agrees with the CM a high percentage of the time with a significant reduction in sample numbers. Although resampling after 2 days was recommended in some cases, the actual number of disagreements where no treatment was recommended by the SSM and treatment was recommended by the CM was very low (0.6%). This SSM is conservative enough to prevent excessive damage to the crop while saving time without sacrificing precision, which was one of the major goals of this project.

These findings suggest that the SSM can significantly reduce the numbers of samples and sampling time needed to make decisions for pest management intervention in collard production and agree very well with the decisions of a more intensive, time- consuming fixed-number sampling method. Three farms in Lexington County have used the SSM during the spring and summer seasons. The farm operators are pleased with the reliability and time efficiency of the method. Collard production has increased in South Carolina (Anonymous 2002) as insecticide applications and pest management costs have decreased in Lexington County (J. P. Smith, unpublished data) after the initiation of a CM. The development of this SSM and subsequent implementation of this method will further benefit the production of collard in Lexington County and other areas of South Carolina and can be tested and introduced into other production areas.

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