Sequential sampling plan for corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), in corn fields on the south coast of Puerto Rico[1,2]

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ABSTRACT

The corn earworm, *Helicoverpa zea* (Boddie), is the major insect pest of corn, *Zea mays* L., in Puerto Rico. The objective of this study was to design a sequential sampling plan with fixed precision levels for *H. zea* (Boddie) in corn fields on the south coast of Puerto Rico. For determining the presence (= 1) or absence (= 0) of *H. zea* eggs, 25 corn plants were randomly sampled from December 2003 to March 2004. Data were analyzed by using the beta binomial distribution. Critical density levels of 0.10 and 0.08 infested plants, before and after the emergence of ear silks, were used for Iwao's and converging lines formulae. A converging line sampling plan is recommended because it selected a smaller average sample size. This plan can be used to make cost effective control decisions on field corn in Puerto Rico.

Key words: corn earworm, sequential sampling, converging lines

RESUMEN

Plan de muestreo secuencial para el gusano de la mazorca, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), en siembras de maíz de la costa sur de Puerto Rico

El gusano de la mazorca, *Helicoverpa zea* (Boddie), es la plaga más importante del maíz, *Zea mays* L., en Puerto Rico. El objetivo de este estudio fue diseñar un plan de muestreo secuencial con niveles fijos de precisión para *Helicoverpa zea* en campos de maíz en la costa sur de Puerto Rico. Para determinar la presencia (= 1) o ausencia (= 0) de huevos de *H. zea,* se exami-

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naron 25 plantas de maíz desde diciembre de 2003 hasta marzo de 2004. Los datos se analizaron utilizando una distribución beta binomial. Se utilizaron niveles de densidad crítica de 0.10 y 0.08 plantas infestadas, antes y después de la emergencia de los filamentos de la mazorca, en las fórmulas de Iwao y de líneas convergentes. Se recomienda el plan de muestreo secuencial de líneas convergentes porque seleccionó un menor número promedio de muestras. Este plan puede ser utilizado para tomar decisiones de control costo efectivas en siembras de maíz de campo en Puerto Rico.

Palabras clave: gusano de la mazorca, muestreo secuencial, líneas convergentes

INTRODUCTION

The first instar larvae of *Helicoverpa zea* feed on green ear silks before boring into the ear, where larval development is completed by feeding on developing corn kernels. The damage caused by the larvae fosters microorganism-born secondary infections which cause further damage in corn ears and increase losses (Storer et al., 2001). The insect is a major pest of field corn planted on the south coast of Puerto Rico (Fuentes-López, 1994), where frequent insecticide applications are required, usually on a calendar basis, to keep this insect species under control.

Damage to field corn by *Helicoverpa zea* can be minimized with early scouting before larval hatch. Pest management specialists have recommended fixed sampling for *H. zea* in corn based on 100 to 400 plants; these samplings require an excessive amount of time (Petzoldt, 1990; Hoffmann et al., 1996). The effectiveness of scouting for *H. zea* can be increased by using sequential sampling plans by which a decision can be made to control the pest when the number of infested plants is equal to or greater than the upper stop value—critical insect population above which economic damage will occur if no control action is taken (Hoffmann et al., 1991; Hoffmann et al., 1996; O'Rourke and Hutchison, 2003; Dawson et al., 2006). Monitoring costs can be reduced without sacrificing reliability by examining only the area of the plant most likely to be attacked by using binomial sampling, where only the presence of organisms on a sample unit is recorded (Wilson and Room, 1982). Knowledge of the dispersion of the pest allows a better understanding of the relationship between an insect and its environment and provides basic information for interpreting spatial dynamics. This knowledge helps to design efficient sampling programs for population estimation and pest management (Taylor, 1984).

Recent studies in Puerto Rico on the phenology and distribution of *H. zea* eggs in field corn indicate that the number of eggs increases during the flowering stage and that they are spatially aggregated on green silks (Calero-Toledo, 2007). Therefore, the presence of *H. zea* eggs should be sampled on corn silks, where they would be more accurately estimated. Clusters or groups of adjacent plants can be sampled instead of plants at random because it would thus save time and effort as acknowledged by Binns et al. (2000); it would be practical to take a cluster of sample units at each location instead of only one sample unit. If the pest is aggregated at the scale of the sample cluster, the variance is increased; therefore, the number of infected sample units per cluster can be analyzed by using the beta binomial distribution (Madden and Hughes, 1999; Binns et al., 2000; Venette et al., 2002). With this fact in mind, the objective of this study was to construct a sequential sampling plan for corn earworm eggs in corn fields in Puerto Rico.

MATERIALS AND METHODS

The presence or absence of *H. zea* eggs was determined from December 2003 to March 2004 in experimental plots of field corn in the municipalities of Salinas and Santa Isabel, Puerto Rico. In the fields, we selected a row of corn at random and began sampling at the 50th plant from the border. To determine the presence or absence of *H. zea* eggs in corn, we sampled clusters of 25 consecutive plants from two fields, and one ear on each plant was selected and scored for the presence (value of 1) or absence of *H. zea* eggs (value of 0) by following the procedure described by Wilson et al. (1983) and Hoffmann et al. (1996).

Data were analyzed by using SAS version 8 (1999a; 1999b) and Infostat/Student version 2.0 (2002). A beta binomial macro program (SAS 8) was run to simulate 1,000 sampling tests with adjusted stop values so that maximum-tolerable error rates approximated the desired error rate (macro available from the second author). The operating characteristic (OC) and the average sample (ASN) functions (curves) were used to evaluate the performance of the sampling plans. The OC function is a graph of the probability of no intervention (or no spray) versus the true population level (plants infested with eggs), thus allowing the sample size to be adjusted to meet desired levels of risk (Nyrop et al., 1999). The ASN is the mean number of sampling units (of n individuals each, with cluster sampling) required to make a decision, given any true value of infestation.

Parameters for the beta binomial macro

The following parameters were assigned for the macro: critical density (cd), alpha, intracluster correlation coefficient (ρ, the Greek letter rho), R, minN and maxN; on the basis of sampling plans tested (Iwao's and sequential sampling). The critical density is the number of insects that indicates the need to apply control measures to avoid economic damage. The parameter alpha is the probability of not spraying when pest populations are high. The intra-cluster correlation coefficient ρ is a measure of the relatedness of clustered data as obtained by comparing the variance within clusters with the variance between clusters. The number of observations that compose each cluster, and the minimum and maximum number of clusters were R, minN and maxN, respectively. The stop values were calculated by using the sequential probability ratio test or converging lines for sequential sampling (Wald, 1947), and the patchiness regression of Iwao (Iwao, 1975).

Critical densities

In developing our sampling plan, we modified critical densities from those used by Hoffmann et al. (1996). We used a proportion of 0.10 plants infested with *H.* zea eggs before silk emergence with an alpha of 0.03, and a proportion of 0.08 infested plants after silk emergence with an alpha of 0.05, using a maximum of 50 samples and a minimum of 15. The critical densities were selected on the basis of the assumption that only 10% of the eggs laid before silk emergence and 8% of the eggs laid after this stage will hatch to larvae. The critical density after silk emergence was lower because most ovicides are applied at this stage and fewer larvae survive.

RESULTS AND DISCUSSION

Simulations of the OC and the ASN functions (Figure 1) were made with the above described critical proportions for the Iwao's and convergent lines' sampling plans. The OC curves on both sampling plans were generated for critical density of 0.10 to satisfy the condition that when mu is equal to 0.8, the probability of intervention approximates 20% and when mu is equal to 1.2, the probability of intervention approximates 80%. The ρ value for R = 25, estimated with the formula described by Binns et al. (2000), was 0.2092. To prove R = 5, ρ was augmented theoretically to 0.22. For the convergent line plan, α was 0.20, minN = 17 and maxN = 120. Iwao's plan representative curve was simulated by using α = 0.05, minN = 7 and maxN = 82. The sample size used in the model, five plants per cluster (R = 5) is realistic and practical under field conditions.

On the basis of 1,000 simulation replicates, we found that for critical densities of 0.10 and 0.08, before and after silk emergence, respectively, the probability of correctly implementing the manage-

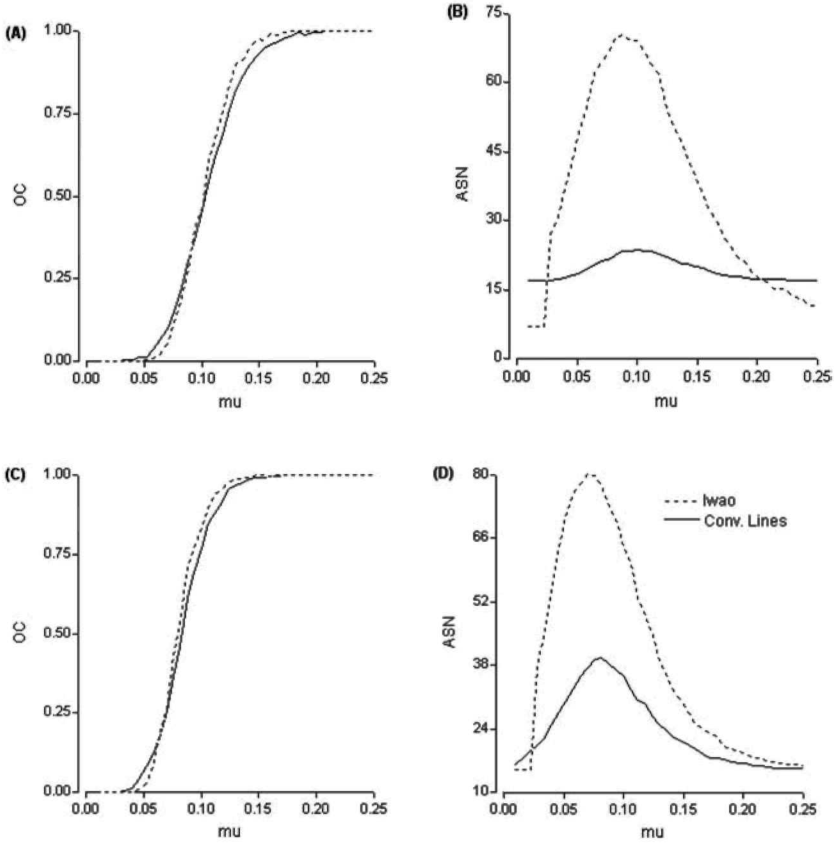

FIGURE 1. Simulations of the OC and the ASN functions. (A) OC, cd = 0.10; (B) ASN, cd = 0.10 (C) OC, cd = 0.08 (D) ASN, cd = 0.08

ment action is over 50% in both sampling plans (Figures 1A and 1C). However, the converging lines sampling plan is recommended because it required a smaller average sample size to achieve a control decision as shown in Figures 1B and 1D. Figures 2 and 3 show the decision lines for the converging lines sampling plan at the presilking (cd = 0.10) and postsilking (cd = 0.08) stages. Inferior and superior limits for cd = 0.10 were five and 12 infested plants accumulated, respectively, for a sample size of 17 clusters (minN). If the sample size is 17 (17 clusters of five plants), a total of 12 or more egg-infested plants need to be accumulated before silk emergence to warrant control measures (Figure 2). Inferior and superior limits for

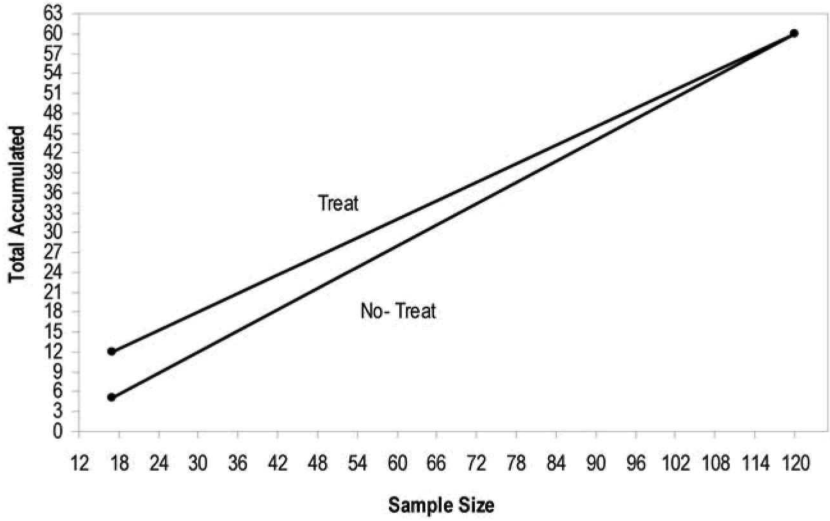

FIGURE 2. Converging lines sequential sampling plan for *H. zea* eggs in corn before silk emergence (cd = 0.10).

cd = 0.08, were one and 12 infested plants accumulated, respectively, for a sample size of 15 clusters (minN) (Figure 3). If the sample size is 15 (15 clusters of five plants), a total of 12 plants infested with eggs must be found after silk emergence to warrant control. In the proposed plan, the scout should record the total of infested plants accumulated and the sample size (number of clusters of five plants each) on the graph. The scout should stop sampling when the accumulated number of infested plants hits values above the upper line or below the lower line of the graph (e.g., Figures 2 and 3).

The efficiency of sequential sampling plans to improve the monitoring of *H. zea* has been reported by several authors for tomato and fresh market corn crops (Hoffmann et al., 1991, Hoffmann et al., 1996; Dawson et al., 2006). The quantification of the temporal pattern of *H. zea* egg densities was demonstrated (Hoffmann et al., 1991), and a 45% savings in complete costs were achieved by using sequential sampling instead of fixed sample size plans (Hoffmann et al., 1996). Since the population dynamics of *H. zea* is related to the availability of its hosts and the phenology of corn (Calero-Toledo, 2007), our sampling plan is expected to provide an efficient cost effective tool for monitoring this pest in corn fields of the south coast of Puerto Rico, particularly as corn is in the flowering stage and planted acreage increases.

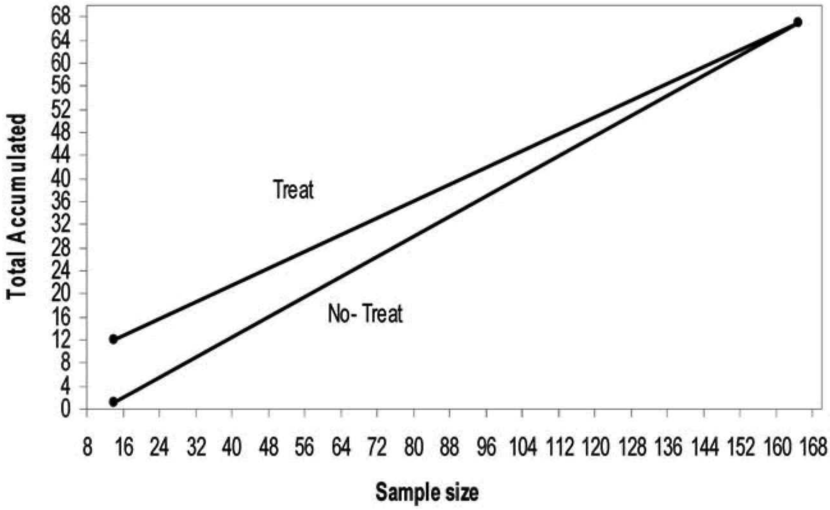

FIGURE 3. Converging lines sequential sampling plan for *H. zea* eggs in corn after silk emergence (cd = 0.08).

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