ADEQUACY OF 100 SQUARE PER FIELD SAMPLING TECHNIQUE FOR ESTIMATING DAMAGE BY BOLL WEEVIL (COLEOPTERA: CURCULIONIDAE) HELIOTHIS VIRESCENS (F.) AND HELICOVERPA ZEA (BODDIE), (LEPIDOPTERA: NOCTUIDAE) IN AN AREA WIDE COTTON IPM PROGRAM

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Abstract

In 1973-75, a sample size of 100 fruiting forms (=squares (flower buds) or small bolls) of cotton per field in the Lower Rio Grande Valley of Texas was used to estimate damage by the boll weevil, Anthonomus grandis Boheman, and either or both bollworm Helicoverpa zea (Boddie), and tobacco budworm, Heliothis virescens (F.). Sampled fruiting forms were tabulated as damaged or undamaged by the boll weevil or the lepidopteran species. Sampling for boll weevil and bollworm/tobacco budworm in each field each year was conducted twice a week in an "X" configuration across conditions of both dryland and irrigated fields. In this area 15,000 to 20,000 fields are planted yearly. Number of fields to sample was determined by binomial distribution from the total number fields sampled on each day during all three years. This estimate for number of 100 forms/field to sample on each day was adequate when the number of times to sample was equal or less than the number of 100 forms/field actually sampled. Dryland cotton fields, with its lower levels of damage, required more intensive sampling than did irrigated cotton fields. Variance increased as mean damage level increased, indicating that mean and variance were directly related. This analysis was conducted to evaluate the efficacy of a sampling method presently used by the Texas Agricultural Extension Service in the LRGV.

Introduction

The decision to initiate an action for insect control in the Lower Rio Grande Valley (LRGV) of Texas is based on sampling, such as that described by Norman et al. (1979). Success of this action is dependent on the reliability of the sample to provide a reasonable estimate of the level of damage. Damage to fruiting forms of 15% or more by the boll weevil, Anthonomus grandis Boheman or 5% or more by the bollworm, Helicoverpa zea (Boddie) and the tobacco budworm, Heliothis virescens (F.), are the criteria used to initiate an action against these pests in the LRGV of south Texas (Cartwright and Norman 1987). Sterling and Pieters (1974) showed that a sample size of 5 to 50 fruiting forms was required to assess damage based on sequential sampling. Wolfenbarger (1977) determined that a sample size following the examination of 100 to 1,000 whole cotton plants in each field was required to assess damage by these pest species. No field scouts in the LRGV have adopted the sequential technique of Sterling and Pieters (1974), but a fixed sample size of 100 squares or bolls/field/sample date has become standard for making decisions relating to the need for applying control measures for these pests by Texas Agricultural Extension Service.

Our objective was to determine if the currently accepted practice of sampling 100 fruiting forms per field serves as an adequate estimator of damage by the boll weevil and the bollworm-tobacco budworm on any given day of sampling dryland and irrigated cotton fields from 1973 to 1975 across the LRGV.

Methods

An "X" configuration (Norman et al. 1979) was used in the LRGV to sample for boll weevil and bollworm and/or tobacco budworm damage to the fruiting forms of cotton in dryland and irrigated fields that measured 5 to 80 ha and 2 to 30 ha, respectively. Two workers/field sampled 2 to 40 fields from calendar day 100 to 235 during the 3 years. Each individual field was sampled twice a week throughout the growing season. Each worker picked 25 bolls or squares at nearly uniform intervals diagonally across each field from opposite corners to the center of the "X" configuration. Then each repeated the process along the arm of the "X" on the same side of the field. Because cotton is usually planted in rotation with sorghum, field locations were not the same each of the three test years.

The fruiting forms were examined to determine whether they were damaged by either the boll weevil or bollworm-tobacco budworm. Data consisted of boll weevil damaged forms and bollworm - tobacco budworm damaged forms/100 sampled, providing a binomial distribution (Wolfenbarger 1977, Wolfenbarger et al. 1980).

Adequacy of the 100-unit sample size/fruiting forms/field was determined from fields sampled each day for the three years across the LRGV. Damaged or undamaged fruiting forms were determined with the binomial formula n (estimated number fields to be sampled)=q(number undamaged/100 forms/(p) times coefficient of variation = standard deviation/mean) where p (the number of damaged squares per 100 squares sampled) = 1-q of Karandinos (1976). An adequate sample size was indicated when the number of times estimated to sample the fields each day was equal or less than the actual number of fields sampled on that day. The distribution assumes replacement of each event after each decision, and squares and bolls are

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continually produced and serve as replacements for those removed and examined (Steel & Torrie 1960).

The results, percentage damaged forms, were subjected to a standard linear regression analysis, $y = a+bX$, to determine the relationship of the mean and variance for each field condition and for pest species.

We used the curvilinear exponential regression equation $Y = ae^{bx}$ to relate actual mean damage vs. sample size estimate for mean damage under dryland and irrigated conditions. We also calculated the correlation coefficient (r) values for that equation at $P_{0.05}$.

Results

Correlation coefficient values (Table 1) indicate a significant negative correlation between the mean percentage damage and variance about that mean in both irrigated and dryland cotton fields. Difference was greater in irrigated than in dryland cotton. The intercept (a) and slope (b) values of these damage estimates for irrigated cotton are greater than those for dryland cotton.

A sample size of 100 forms was sufficient to estimate boll weevil damage in dryland cotton fields on 48% of the 71 sampling dates (Figure 1). In irrigated fields, the 100 fruiting form samples adequately estimated damage on 63% of the 81 sample dates (Figure 2).

Boll weevil damage of $\geq$15%, considered to be the action threshold, occurred on only two sampling dates (3%) in the dryland fields, and on one of those dates only one sample of 100 forms/ field was required. Damage of $\geq$15% occurred on 11 sampling days (14%) in irrigated fields (Figure 2) and only one 100 - unit sample/field was required on 91% of those days.

Bollworm-tobacco budworm damage of $\geq$ 5%, considered to be the action threshold, occurred on seven of the sampling dates (2%) in dryland fields (Figure 3). Sample size estimates of damaged forms by these lepidopteran pests were sufficient on only 4% of the 67 sample dates.

A damage level $\geq$ 5% was reached on 36 of the 84 sampling days (43%) in irrigated fields (Figure 4). On 39% of the sample dates one or fewer 100 form samples/field were needed. Damage levels caused by these lepidopteran requires more sampling when only 2% of the sampling dates have mean damage levels of $\geq$5% than when 43% have mean damage levels of $\geq$5%.

The number of consecutive days during the season that fields were adequately sampled (Table 2) was determined. Data derived from the sampling of damage for these pests were more consistent in irrigated than dryland cotton. Twice during the season the 100 sample unit for the boll weevil/irrigated field was adequate for eight consecutive days. This means that we can adequately sample fields day after day across the LRGV for the boll weevil and be confident that we determined the damage level by this insect.

For boll weevil, $\geq$ 15% damage/field occurred 71% and 62% of the total days sampled in dryland (Figure 1) and irrigated cotton (Figure 2), respectively. For bollworm-tobacco budworm, $\geq$ 5% damage/field occurred 0% and 33% of the days sampled in dryland (Figure 3) and irrigated fields (Figure 4), respectively. Sampling for damage by the boll weevil is more reliable and consistent than for damage by the bollworm-tobacco budworm.

Utilizing curvilinear exponential regression equation $Y = ae^{bx}$, the correlation coefficient values for mean damage (X) by each pest species vs. sample size (Y) (data not shown in table) in both irrigated and dryland cotton was significant at $P_{0.05}$ with 1 exception. Sample size vs. bollworm-tobacco budworm damage in dryland cotton fields was not significant (r=0.09 for df=73).

The r=0.35 for df = 90 was significant for bollworm-tobacco budworm damage in irrigated cotton. The correlation coefficients for the boll weevil in dryland and irrigated cotton were r=0.27 for df=74 and r=0.29 for df=84, respectively, and both were significant. However, all significant values show that the regression for adequate sample size accounted for $\leq$35% of total variability. The curvilinear curve was used rather than the linear regression because it provided a better fit of the data.

Discussion

Our results suggest that, for any given field in such a broad and representative area as the LRGV, 100 fruiting forms/field are sufficient to determine damage by boll weevil and bollworm-tobacco budworm 4 to 63% of the days based on twice-weekly sampling in an "X" configuration on any given day during a 3 year time span. Results show that sampling for damage by the boll weevil is more accurate than it is for the bollworm-tobacco budworm. This is because the threshold of damage is higher for the boll weevil than for the bollworm - tobacco budworm.

Geologically the LRGV is an alluvial flood plain, 150 km. long by 16 km. and 64 km. wide at either end. While edaphic conditions are variable, all cotton is planted within a 45 day period and harvested 6 months later. Fruiting time is fairly consistent throughout this area. The sample size estimates presented here would be applicable throughout the whole area.

The central limit theorem of statistical method forms the basis of these sample size determinations (Campbell 1974). Two to 40 or more fields/sample date follows an approximation of the normal distribution. No limitations on time or space for this theorem are made. We are justified in determining sample size estimates over years in the same geographic area even though they are determined over a range of environmental conditions.

The binomial method of calculating adequate sample sizes for determining damage by feeding and oviposition of the boll weevil and feeding of the bollworm-tobacco budworm disclosed wide variations in sample size estimates among the sampling dates. Such variations are typical and their disadvantage may be offset by sampling at intervals of no more than 4 days, where under estimates of damage may be compensated in sufficient time to initiate or postpone control measures.

This information would be useful in the implementation of an area-wide eradication program against any of these insects where one treatment is applied to cotton fields in tropical areas. Knowledge about probabilities of under-sampling would help to determine which and how many fields to re-sample to support or reject conclusions of previous samplings.

From a theoretical view, the same percentage damage can be determined with a sample of 50, as compared to a sample of 100, providing the assumptions hold (Table 3). The difference in the sample size is found in the width of the confidence interval. For example, the confidence interval for a sample size of 50 and expected positives of 15% (for boll weevil) is 5 to 25 (± 10). Compared to a sample size of 100 for the same insect, expected positive of 15%, the confidence interval is 8 to 22 (± 7).

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Table 1. Linear regression equation to determine adequacy of sampling 100 squares or bonus/field for boll weevil and bollworm/tobacco budworm damage to dryland or irrigated cotton, LRGV, TX 1973-75.

Cond. of Fields	Pest	Days Fields Sampled	% Damage	Variance	Degrees of Freedom	Correlat. Coeff.	Equation Y=a+bx
Irrigated	Boll Weevil	71	8	110	84	-0.66	Y=17.1-26.7x
	Bworm/ T.Bud	81	4	27	90	-0.69	Y=9.7-15.7x
Dryland	Boll Weevil	67	6	56	74	-0.57	Y=7.7-6.7x
	Bworm/ T.Bud	84	2	7	73	-0.55	Y=3.2-0.8x

Table 2. Frequency of consecutive days during season when number fields to sample during season were equal to or less than 100 squares or bolls/field actually determined, Lower Rio Grande Valley, TX 1973-75.

Consecutive Days	Frequency: Boll Weevil Dryland	Boll Weevil Irrigated	Bollworm/tobacco budworm Dryland	Bollworm/tobacco budworm Irrigated
2	4	8	3	14
3	8	8	0	4
4	3	1	0	1
5	1	1	0	2
6	0	1	0	0
8	0	2	0	0

Table 3. Influence of sample size on expected proportion and 95% confidence limits when expected damage is 15% using normal approximation to binomial.

Observation	Number Sample	Lower Confidence Limit	Expected	Upper Confidence
1	5	-16.2987	15	46.2987
2	10	-7.1315	15	37.1315
3	15	-3.0703	15	33.0703
4	20	-0.6493	15	30.6493
5	25	1.0028	15	28.9972
6	30	2.2224	15	27.7776
7	35	3.1702	15	26.8298
8	40	3.9342	15	26.0658
9	45	4.5671	15	25.4329
10	50	5.1025	15	24.8975
11	55	5.5631	15	24.4369
12	60	5.9648	15	24.0352
13	65	6.3193	15	23.6807
14	70	6.6351	15	23.3649
15	75	6.9187	15	23.0813
16	80	7.1753	15	22.8247
17	85	7.4090	15	22.5910
18	90	7.6228	15	22.3772
19	95	7.8196	15	22.1804
20	100	8.0014	15	21.9986

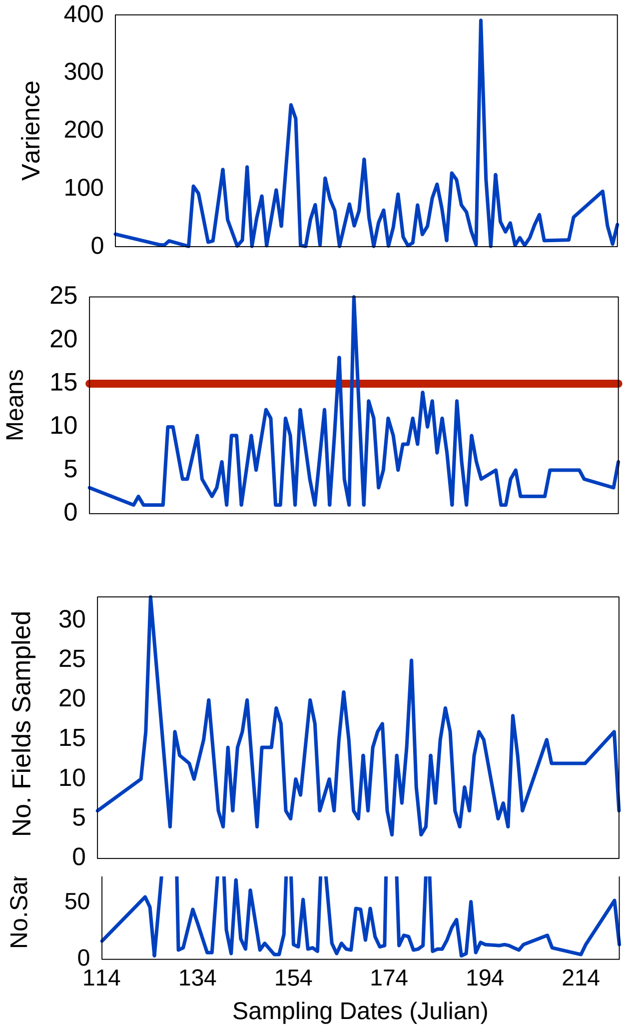

Figure 1.Variance and mean number of boll weevil damaged squares of cotton/100 squares sampled in indicated fields under dryland growing conditions required to provide reliable estimates when data were subjected to calculation by the binomial formula, n = q/(p)(CV^2) in the LRGV, Texas, 1973-75.

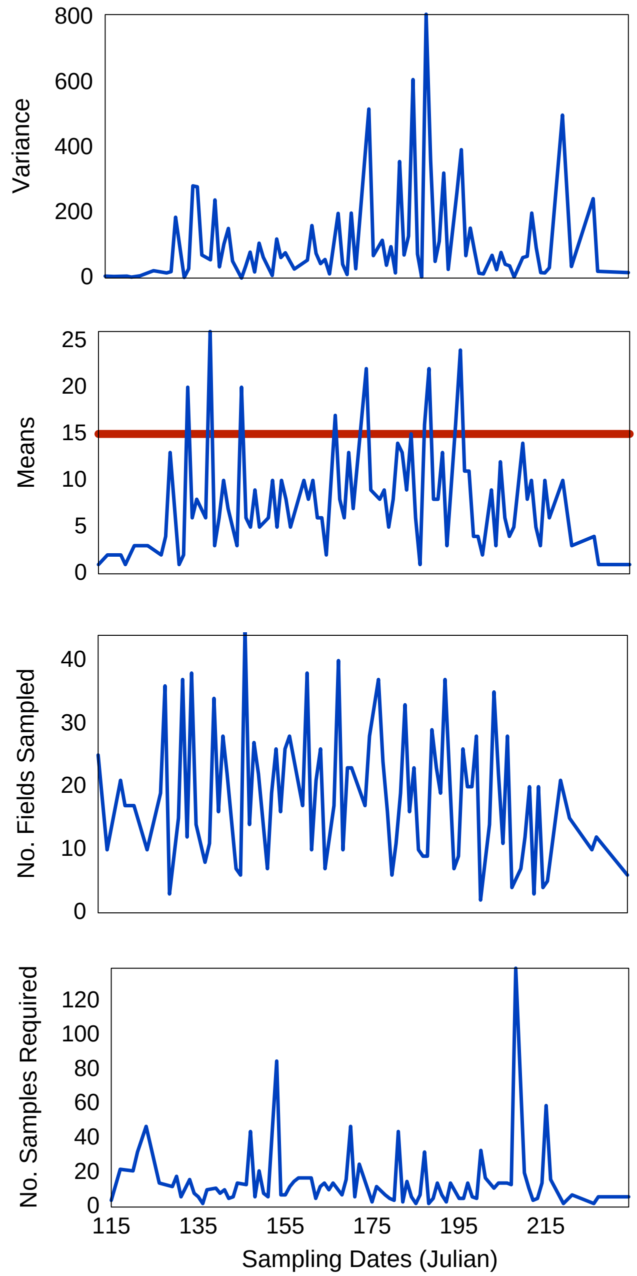

Figure 2. Variance and mean number of boll weevil damaged squares of cotton/100 squares sampled in indicated fields under irrigated growing conditions required to provide reliable estimates when data were subjected to calculation by the binomial formula, n^2 = q/(p)(CV^2) in the LRGV, Texas, 1973-75.

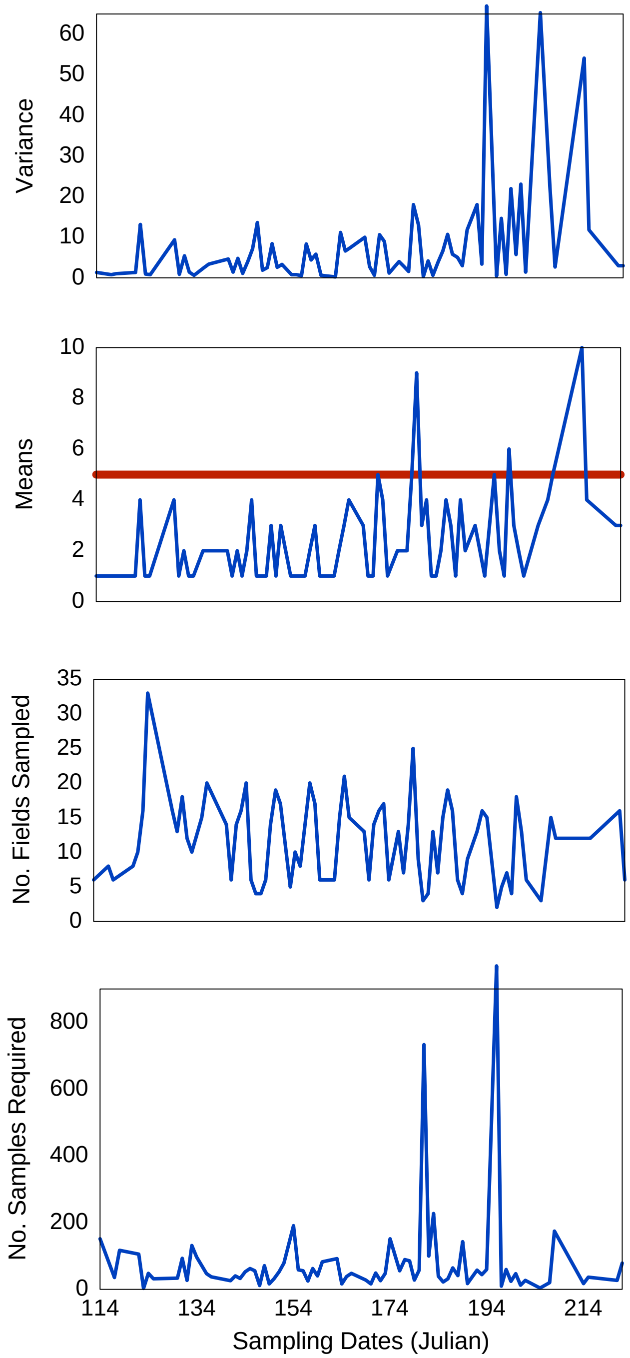

Figure 3. Variance and mean number of bollworm-tobacco budworm damaged squares of cotton/100 squares sampled in indicated fields under dryland conditions required to provide reliable estimates when data were subjected to calculation by the binomial formula, $n = q/(p)(CV^2)$ in the LRGV, Texas, 1973-75.

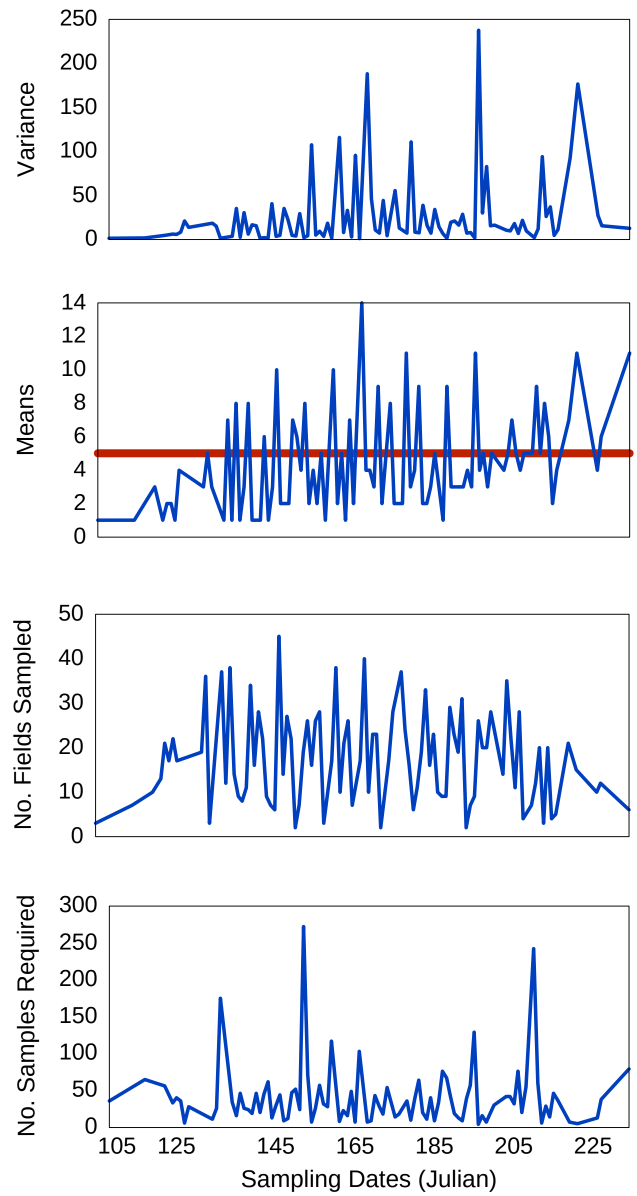

Figure 4. Variance and mean number of bollworm-tobacco budworm damaged squares of cotton/100 squares sampled in indicated fields under irrigated conditions required to provide reliable estimates when data were subjected to calculation by the binomial formula, $n = q/(p)(CV^2)$ in the LRGV, Texas, 1973-75.