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Variable intensity sampling: Developing operational plans for the green rice leafhopper in wet paddy ecosystem in Malaysia

(Pensampelan keamatan berubah: Menghasilkan pelan operasi untuk bena hijau dalam ekosistem sawah di Malaysia)

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Key words: green leafhopper, rice, sample plan, VIS, Taylor's coefficients, Malaysia

Abstrak

Skim pensampelan baru yang disebut sebagai pensampelan keamatan berubah (VIS) dicadangkan bagi serangga perosak padi iaitu bena hijau (*Nephotettix* spp.). Parameter *a* dan *b* dalam Hukum Kuasa Taylor (TPL) digunakan untuk menghasilkan pelan VIS ini. Anggaran kepadatan populasi dan sifat penentuan tindakan dijana daripada data yang diperoleh dari empat petak sawah penyelidikan di Universiti Putra Malaysia selama 73 hari. Empat tarikh pensampelan dipilih untuk kajian ini. Data yang diperoleh sepadan dengan TPL dan dapat ditunjukkan sebagai $\ln s^2 = 0.24 + 1.30\ln\bar{x}$ (s^2 = varians, $\bar{x}$ = min kepadatan). Tahap ketepatan 0.25 dan nilai ambang tindakan ekonomi dua ekor bena hijau setiap rumpun dipilih untuk menghasilkan pelan ini. Dalam pelan ini, bilangan purata sampel yang diperlukan berjulat antara 13 hingga 48. VIS-TABLE untuk mengambil sampel dan VIS-CHART untuk menentukan bilangan sampel yang diperlukan turut dikemukakan.

Abstract

A relatively new sampling scheme called the variable intensity sampling (VIS) has been proposed for a rice pest, the green leafhopper (GLH), *Nephotettix* spp. Taylor's Power Law (TPL) coefficients *a* and *b* were used in developing the VIS plan. Population density estimations and decision making attributes were derived from data obtained from four experimental plots at Universiti Putra Malaysia for a sampling period of 73 days. Four sampling occasions were chosen for analysis. The data fit well the TPL and are represented as $\ln s^2 = 0.24 + 1.30\ln\bar{x}$ (s^2 = variance, $\bar{x}$ = mean density). A precision level of 0.25 and an economic threshold of 2 hoppers/hill were selected in developing this plan. The average sample number required in VIS ranged from 13 to 48. The VIS-TABLE for sampling and the VIS-CHART for determining the required sample size for GLH are presented.

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Introduction

Plant and leafhoppers constitute a large group of phytophagous insects of which many are of major economic importance. In the Malaysian paddy ecosystem, the green leafhopper (GLH) *Nephotettix* spp. and planthoppers *Recilia dorsalis* (Motschulsky), *Nilaparvata* spp. and *Sogatella furcifera* (Horvath) are major pests. GLH damages the rice plant by sucking the plant sap and acting as a vector of rice tungro virus (Rivera and Ou 1965). In early 1981, this virus infected approximately 700 ha of rice field in the northern part of Peninsular Malaysia and reduced rice yield by about 40%, even though chemical pesticides such as BPMC, MIPC or carbaryl with 0.1% active compound were sprayed weekly during seedling stage, then in the first and second weeks after transplanting (Anon. 1981). However, synthetic chemicals are toxic to the environment and public health (Jeyaratnam et al. 1987; Escalada and Heong 1993; Mahmud 1994). Consequently, a national pest surveillance program was designed by the Malaysian Agricultural Research and Development Institute (MARDI) and implemented by the Department of Agriculture (DOA) in 1979 to provide better pest control decision making (Mahmud 1994).

Forecasting and monitoring/ surveillance sampling schemes are an integral component of integrated pest management (IPM) strategy (Wilson et al. 1989). In Malaysia, to date, almost all monitoring/surveillance assignments use the fixed sample size (FSS) sampling plan to estimate the population density of a particular pest. In some areas, scattered surveys are conducted weekly using FSS plan and farmers are adviced on need to spray based on perceived static economic injury levels (Mahmud 1994). However, this method is not only inefficient, laborious and costly, but its reliability and error rates are also unknown (Sterling and Pieters 1979; Hassan and Rashid 1997a).

Sampling programs for monitoring field population of insect pests need a clearly defined sample unit and must provide reasonable population estimates while minimizing sampling effort (Southwood 1978). If the sampling objective is simply to rapidly classify an insect population density as above or below a critical threshold, then collecting many samples is not always necessary (Legg and Barney 1988; Brewer and Trumble 1991; Legg et al. 1994).

Sequential sampling as developed by Wald (1945) is a well established method in pest management for many insects in a wide array of crops (Pieters 1978). In paddy ecosystem, there are some studies on sequential plans used for making pest management decision. Most of these studies focused on one target species at a time (Nishida and Torii 1970; Kuno 1977; Shepard et al. 1986; Ferrer and Shepard 1987; Shepard, Ferrer et al. 1988; Shepard, Minnick et al. 1988; Bianchi et al. 1989) with little emphasis, except in Shepard et al. (1989), on developing plans for the predators. In contrast, since more than one species of pests and predators are usually found simultaneously in a paddy crop, Hassan and Rashid (1997a) recently developed sequential sampling plans for 22 categories of pests and predators. Sequential sampling permits rapid, efficient and easy classification of populations for decision making (Waters 1955; Pieters and Sterling 1974; Sterling 1975; Shepard and Ferrer 1990; Hassan and Rashid 1997a).

Here, we propose a relatively new sampling scheme, for a paddy pest, called variable intensity sampling (VIS) which was originally developed by Hoy et al. (1983). This scheme is based on the idea that at any time, a range of population densities exists for any given field, and VIS relies on a range of critical population densities to justify treatment rather than the exact economic threshold. Thus, the essence of changing critical threshold in relation to varying densities is incorporated. Although the main objective of this sampling scheme is not for decision making, Shelton et al. (1994) indicated that it is an effective method to assist in making treatment decisions.

In developing a VIS plan for a paddy pest, our usage of population distribution parameters is different from that of Hoy et al. (1983). We use the relationship between the mean and the variance in Taylor's Power Law (TPL) (Taylor 1961, 1984) rather than on assumptions of an underlying distribution of the pest population. Taylor (1961, 1984), and Shelton and Trumble (1991) show a consistent variance (s^2) and mean ($\bar{x}$) relationship in many animal and insect species, as expressed by the following regression:

$$\ln s^2 = \ln a + b \ln \bar{x} \qquad \text{Eqn. 1}$$

The slope *b* of this regression is a measure of aggregation, and the intercept *a* is simply a sampling factor related to sample size (Taylor 1961). The coefficients *a* and *b* are species-specific and widely used for describing insect dispersion (Wilson and Room 1983; Pickett and Gilstrap 1986; Azhar and Long 1991; Smith and Hepworth 1992; Rashid et al. 1994; Hassan 1996), and for developing sampling program for pest management (Shelton et al. 1987; Thistlewood 1989; Hollingworth and Gatsonis 1990; Azhar and Long 1991; Shelton and Trumble 1991; Roux et al. 1992; Cho et al. 1995; Hassan and Rashid 1997b). Another difference from Hoy et al. (1983) is that we substitute temporal segments for spatial segments in generating the operational sampling plan.

This paper reports on the development of a VIS plan based on TPL for both population density estimation and making treatment decision for *Nephotettix* spp. in the paddy ecosystem. The mathematical algorithms and schematic procedures of operation, and statistical results of the VIS plan are presented.

Materials and methods

Development of the variable intensity sampling plan

The procedure generally followed that of Hoy et al. (1983) with the exceptions that TPL coefficients *a* and *b* were used and the segment (spatial) parameters were replaced by the time-interval (temporal) parameters within a sampling occasion or date. The sample variance was calculated based on TPL. Subsequently, we used the general optimum sample size (OSS) formula (Karandinos 1976) as simplified by Wilson and Room (1982) by incorporating Taylor's coefficients to predetermine the required OSS. Recently, Hassan and Rashid (1997b) have established an OSS scheme for 22 categories of paddy arthropods based on the predetermined Taylor's coefficients by Rashid et al. (1994) and Hassan (1996). An OSS curve can then be used to determine the required sample size at various mean densities. The OSS formula to estimate the predetermined optimal sample size (N_{OSS}) with respect to mean threshold ($\bar{x}_{thr}$) is

$$N_{OSS} = (Z_{\alpha/2} / D)^2 \, (a \bar{x}_{thr}^{\,b-2}) \qquad \text{Eqn. 2}$$

where $Z_{\alpha/2}$ = upper $\alpha/2$ point of the standard deviations of the threshold

D = reliability or precision required, expressed as a fixed proportion of the mean

Therefore, the maximum sample number (n_{max}) of hills that should be examined within a time interval on a specified date of sampling can be calculated from the expression

$$n_{max} = N_{OSS} / T \qquad \text{Eqn. 3}$$

where T = total number of time intervals within a sampling date

The sample size needed to achieve the required precision is calculated as a function of the mean. The 95% confidence interval (CI) for the mean threshold ($\bar{x}_{thr}$) with a normal approximation is

$$\bar{x}_{thr} \pm Z_{\alpha/2}[\sqrt{s^2_{(\bar{x}_{thr})}/n}\ ]$$

Thus, the estimated mean density ($\bar{x}$) can be equated to the above CI as

$$\bar{x} = \bar{x}_{thr} \pm Z_{\alpha/2}[\sqrt{s^2_{(\bar{x}_{thr})}/n}] \qquad \text{Eqn. 4}$$

where $s^2_{(\bar{x}_{thr})} = a(\bar{x}_{thr})^b$
n = sample size

In VIS scheme, if the estimated mean density ($\bar{x}$) falls within $\pm Z_{\alpha/2}$ standard error of the threshold, the optimal sample size (N_{OSS}) is required and the maximum number (n_{max}) of hills will be sampled at the next time interval. If the estimated mean density ($\bar{x}$) is less than the threshold, the upper limit of the confidence interval is used, and the sample size (n) is

$$n = (Z_{\alpha/2})^2 [s^2_{(\bar{x}_{thr})}]/(\bar{x}_{thr} - \bar{x})^2 \qquad \text{Eqn. 5}$$

If the estimated mean density ($\bar{x}$) is greater than the threshold, the lower limit of the confidence interval is used, then the sample size (n) is

$$n = (Z_{\alpha/2})^2 [s^2_{(\bar{x}_{thr})}]/(\bar{x} - \bar{x}_{thr})^2 \qquad \text{Eqn. 6}$$

The desired sample size to be sampled throughout the time interval can be calculated using equation 5 or 6.

The number of hills to be sampled at any time interval (t) is adjusted based on the number taken thus far for *k* time interval (n_k), and the sampling intensity given in the time intervals (SI_t) is generalized as

$$SI_t = (n - n_k) / [(T + 1) - t] \qquad \text{Eqn. 7}$$

where $t = 1, 2, ..., T$
$k = t - 1$

Thus, the sampling intensity (SI) for the first time-interval (t = 1) that can be calculated from equation 7 is

$$SI_{t1} = N_{OSS}/T = n_{max} \qquad \text{Eqn. 8}$$

where $n = N_{OSS}$
$n_k = 0$ at $t = 1$

Solution of the equation 8 shows that SI at the initial sampling interval (t_1) was equal to maximum sampling intensity (n_{max}) in equation 3. Also, it indicates that all sampling units (n_{max}) must be examined at the initial segment (Hoy et al. 1983). This is true because SI provides information in terms of sample number per time-interval, whereby the desired sample size should be defined before the sampling.

The upper and lower limits of this sampling plan (UL and LL respectively) are defined in terms of the confidence interval. Equation 4 is multiplied by the number of observations (n) to get the VIS critical range as

$$UL = n\bar{x}_{thr} + Z_{\alpha/2} [\sqrt{ns^2_{(\bar{x}_{thr})}}] \qquad \text{Eqn. 9}$$

$$LL = n\bar{x}_{thr} - Z_{\alpha/2} [\sqrt{ns^2_{(\bar{x}_{thr})}}] \qquad \text{Eqn. 10}$$

The sampling procedure is terminated after all time intervals have been considered. The decision not to treat is made when $n\bar{x}$ is smaller than the lower limit, and treatment is suggested when $n\bar{x}$ is greater than the upper limit, while no decision is made when $n\bar{x}$ lies in between the critical range.

Sampling plan development

Sampling Direct visual counts on adults and nymphs of GLH were conducted at Universiti Putra Malaysia (UPM), Serdang, Selangor (3° 2' N, 101° 42' E). Four adjacent plots (each measuring 30 m x 26 m) were transplanted with 21-day-old seedlings of MR 84 rice variety on 7 January 1991. No insecticides were sprayed during the entire sampling period of 73 days. Weekly sampling commenced on 20 February through 2 May 1991 using one hill as the sampling unit. Direct visual counting of individual arthropod was recorded using cassettes. Weekly examination of 20 hills/plot was conducted at 3-h intervals, during each 24-h duration. For sampling during the night, waterproof torchlights with 6V superheavy *Eveready*® batteries were used to examine the hills. The arthropods examined were easily recognized under this light. The sampling path taken by walking through the field was varied from diagonal to zig-zag and semi-circle to ensure a good coverage when sampling each plot.

Dispersion analysis The means and variances of number of adults and nymphs were calculated using PROC MEANS (SAS Institute Inc. 1985) for each time interval and sampling date. Dispersion indices were calculated using TPL (Taylor 1961) variance-mean regression as described in equation 1. Simple linear regression analyses of lns^2 and ln$\bar{x}$ were conducted using PROC REG (SAS Institute Inc. 1985). The data on *Nephotettix* spp. indicates a good fit to TPL *(Figure 1)* with the slope coefficient b of 1.30 (significantly >1.0 with p <0.01, n = 82, adjusted r^2 = 0.74 and MSE = 0.40). The regression analysis indicates that adults and nymphs of *Nephotettix* spp. were aggregated and the relationship between variance-mean can be represented as $\ln s^2 = 0.24 + 1.30 \ln \bar{x}$. Taylor's coefficients a and b were then used to construct the sampling plan. The plan was developed with a precision level of 0.25, a reasonable range for pest management purposes (Southwood 1978).

Results and discussion

Sampling plan development

The resulting VIS plan for *Nephotettix* spp. based on the economic threshold of 2 hoppers/hill (1–29 days after transplanting) is shown in VIS-TABLE *(Table 1)*. A chart namely VIS-CHART was then generated at D = 0.25 *(Figure 2)* that can be used to determine the required sampling intensity (sample size) in the next time interval given the number of hills sampled and the cumulative number of insects recorded. The average sample number generated in VIS sampling ranged from 13 to 48 *(Table 2)*. The required sample size was reduced when the estimated means were less or greater than the lower or upper limit respectively.

Sampling plan requirements and operations

Several parameters are obtained prior to and during development of the sampling plan. TPL coefficients were obtained by

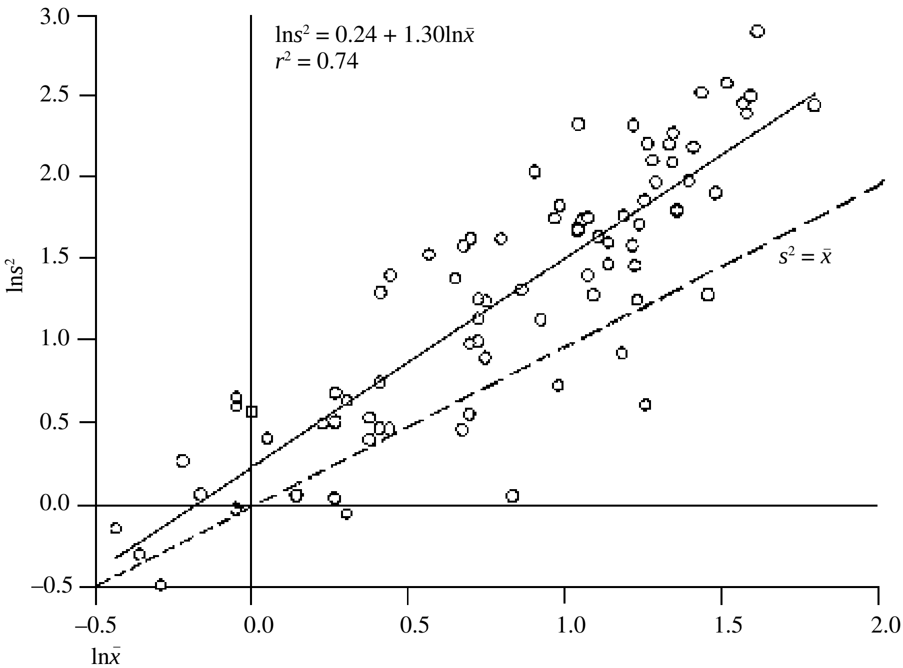

*Figure 1. Regression analysis of lns^2 on ln$\bar{x}$ for the number of **Nephotettix** spp. (both adults and nymphs) on 20 hills at different times and sampling dates (n = 82). The regression slope was greater than that expected for a random dispersion ($s^2 = \bar{x}$) indicating that the adults and nymphs of this species were aggregated*

Table 1. VIS-TABLE of variable intensity sampling plan for *Nephotettix* spp. in rice

VIS-TABLE FOR HOPPER PEST OF RICE

Date:		Day after transplanting:	
Location:		Maximum sampel:	
Field/Plot no.:		No. of segments:	
Variety:		D:	
Species:	*Nephotettix* spp.	Threshold:	2 hoppers/hill
Taylor *a*:	1.27	Lower limit:	1.499
Taylor *b*:	1.30	Upper limit:	2.500

Segment no.	Sample no.	No. hoppers	Cum. no		Lower limit		Upper limit	
	1			No intervene		Continue sampling		Intervene
	2							
	3							
	4							
	5							
1	6			<	9		15	>
	7			<	10		18	>
	8			<	12		20	>
	9			<	13		23	>
	10			<	15		25	>
	11			<	16		28	>
	12			<	18		30	>
	13			<	19		33	>
	14			<	21		35	>
	15			<	22		38	>
	16			<	24		40	>
	17			<	25		43	>
	18			<	27		45	>
	19			<	28		48	>
	20			<	30		50	>
	21			<	31		53	>
	22			<	33		55	>
	23			<	34		58	>
	24			<	36		60	>
	25			<	37		63	>
	26			<	39		65	>
	27			<	40		68	>
	28			<	42		70	>
	29			<	43		73	>
	30			<	45		75	>
	31			<	46		78	>
	32			<	48		80	>
	33			<	49		83	>
	34			<	51		85	>
	35			<	52		88	>
	36			<	54		90	>
	37			<	55		93	>
	38			<	57		95	>
	39			<	58		98	>
	40			<	60		100	>
	41			<	61		103	>
	42			<	63		105	>
	43			<	64		108	>
	44			<	66		110	>
	45			<	67		113	>
	46			<	69		115	>
	47			<	70		118	>
	48			<	72		120	>

Table 2. Results of using variable intensity sampling plan based on Taylor's variance-mean regression model ($\ln s^2 = 0.24 + 1.30 \ln \bar{x}$) on the economic threshold of 2 hoppers/hill (1–29 days after transplanting) and D = 0.25 for *Nephotettix* spp. at Universiti Putra Malaysia transplanted rice plot during the 1991 growing season

Date	Mean density	Decision	s^2	Av. sample no.
20 Feb. 1991	1.231	No intervention	1.664	13
25 Feb. 1991	1.458	No intervention	2.073	48
5 Mar. 1991	2.256	No intervention, continue again in the next 5–7 days	3.655	43
12 Mar. 1991	3.722	Intervention	7.011	18

$s^2 = a\bar{x}^b$, where a and b are Taylor's coefficients

VIS-CHART
Pest: *Nephotettix* spp.
Maximum sample: 48
No. of time-interval: 8
D: 0.25

Cumulative no. of hoppers	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
30	1	1	1	1	2	3	6	6	6	6	6	6	6	6	6	5	4	3	3	2	2	2	2	2	2	1	1
29	1	1	1	1	2	4	6	6	6	6	6	6	6	6	5	4	3	3	2	2	2	2	2	2	1	1	1
28	1	1	1	1	2	5	6	6	6	6	6	6	6	5	4	3	3	2	2	2	2	2	2	1	1	1	1
27	1	1	1	2	3	6	6	6	6	6	6	6	6	4	4	3	3	2	2	2	2	2	1	1	1	1	1
26	1	1	1	2	4	6	6	6	6	6	6	6	5	4	3	3	2	2	2	2	2	1	1	1	1	1	1
25	1	1	1	2	6	6	6	6	6	6	6	5	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1
24	1	1	2	3	6	6	6	6	6	6	6	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1
23	1	1	2	5	6	6	6	6	6	6	5	4	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1
22	1	1	3	6	6	6	6	6	6	5	4	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1
21	1	2	4	6	6	6	6	6	6	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
20	1	2	6	6	6	6	6	6	5	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
19	1	3	6	6	6	6	6	5	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
18	2	5	6	6	6	6	6	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	2	6	6	6	6	6	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	3	6	6	6	6	5	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	6	6	6	6	6	4	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	6	6	6	6	4	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	6	6	6	5	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	6	6	6	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	6	6	4	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	6	5	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

No. of hills inspected

Values inside the chart represent the number of hills to be examined in the next temporal segment

Figure 2. VIS-CHART shows the required number of hills to be examined by using variable intensity sampling plan for ***Nephotettix*** *spp. at Universiti Putra Malaysia transplanted rice plot (1991)*

regressing $\ln s^2$ on $\ln\bar{x}$ as equation 1 and a fixed precision level is predetermined (D = 0.25). Generally, estimates of coefficient become more reliable at a higher precision level. However, required sample size increases. The precision of the estimates is generally expressed as a proportion of the mean. There are two approaches defining precision, i.e. standard error of the mean (C) and a fixed proportion of the mean (D). The relationship of these two values within 95% confidence interval is D = 1.96C (D ≅ 2C).

Combination of the above parameters and predetermined economic threshold (2 hoppers/hill) are used to calculate the optimum sample size (N_{OSS}) using equation 2. The numbers of segments (N_{SEG}) or time intervals (N_T) within a sampling occasion are determined. The maximum sampling unit (n_{max}) in a temporal segment or a time interval can then be calculated by dividing the N_{OSS} with N_{SEG} or N_T.

Operating the VIS-TABLE

Direct visual counting of hoppers can be used for this sampling plan with a hill selected as a sampling unit. The sampler walks in a zig-zag, *X* or *W* pattern through the entire field or selected portion of a field. Initially, the sampler should examine the predetermined maximum sample (n_{max}) of hills in a particular temporal segment or time interval. As the sampler operates the plan, the number of hoppers counted is recorded in column 3 of VIS-TABLE *(Table 1)* for each sample in sequence, as numbered in column 2. The running total (cumulative number of hoppers) is recorded in column 4. After recording all the required samples for the first temporal segment, the sampler should compare the running total (column 4) with the values of the lower limit (column 6) and the upper limit (column 8). In the plan presented here *(Table 1)*, the sampler has to make a comparison at the sixth sample which is marked with number 1 (column 1) representing the first segment. There are three possibilities then, i.e. either the running total is less than the lower limit or larger than the upper limit or intermediate between the lower and the upper limits. If the running total falls between the lower and the upper limits, then the n_{max} of hills should be examined for the next temporal segment. If the running total is less than the lower or greater than the upper limit, the sampler should consult the VIS-CHART *(Figure 2)* to obtain the number of hill(s) that should be examined for the next segment. The number of hill(s) to be examined is then added below the previous segment and the segment numbering 2 (in this case) in column 1. The sampling and comparing processes are repeated until all the predetermined segments required are examined, and a decision is made to intervene when the running total is greater than the upper limit or not to intervene when the running total is less than the upper limit. If the running total still lies between the upper and the lower limits, the sampling program should continue in the next 5–7 days. Such repetitive examination of segments ensures a wider coverage of the field, thus eliminating missing of "hot spots" of high pest densities.

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