Sequential Sampling Plan for Decision Making to Manage Rice Brown Planthopper *Nilaparvata lugens*

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Abstract

Sequential Sampling plan for rice Brown planthopper, Nilaparvata lugens *Stal. was developed based on the negative binomial distribution pattern. The plans were developed for both 'with predator' and 'without predator' cases and decision lines were formulated for light verses severe infestations. Based on the sampling plans, operating characteristic curve and average sample number curve were drawn to find out the probability of taking correct decision and number of samples required at various infestation levels, and the results indicated that the sampling plans derived were efficient and accurate.*

Keywords: Sequential Sampling, Rice brown planthopper

Introduction

Brown Planthopper (BPH), *Nilaparvata lugens* Stal. is one of the major insect pests that attack the rice crop. Although pesticide applications should be made only when pest population exceeds a threshold level, growers often apply these chemicals indiscriminately. This practice is expensive and contributes to pest resurgence and environmental pollution. To determine necessity for a chemical treatment, a sampling technique that is reliable, inexpensive and easy to use should be developed. Proper timing of application of chemical is cost effective and will also help to conserve natural enemies that are vital in regulating populations of brown planthoppers.

A rapid sampling method of classifying populations into broad categories such as light, medium and heavy was developed by Wald (1945) and is known as sequential sampling. This sampling method is useful in pest management to determine the necessity for insecticide treatments. In sequential sampling, samples are taken in sequence and decision to take next sample depends on what is found in the one just made. Using this technique low number of samples can be taken when the population density is low or high, unlike in most of the conventional techniques, which require a fixed number of sampling units.

Sequential sampling plans were developed earlier for many insect pests including Potato leaf hopper, *Empoasca fabea* Harris (Shields and Specker, 1989), Green clover worm, *Plathypena scabra* (F.) (Hammond and Pedigo, 1976), Cabbage looper on cauliflower, *Trichoplusia ni* Hubner (Harcourt, 1966), Cotton boll weevils, *Anthonomous grandis* Boheman (Pieters and Sterling, 1975), Planthoppers in rice, *Nilaparvata lugens* Stal. (Shepard *et al.,* 1986) Plant hoppers and predators in rice (Shepard et al., 1988).

Materials and methods

Development of sequential sampling plan

The Sequential sampling plan was developed by using the data, which were collected from farmers' fields at Kolakaluru village in Guntur district of Andhra pradesh. Five sets of sampling data of brown planthopper were collected in *Kharif* season, while two sets of data were collected from *Rabi* season. Data of field samples were tested to know the distribution pattern of BPH.

Formulae for computing the decision lines (d1 and d2) of the sequential sampling plan were as per Waters (1955), Shepard (1980), Southwood (1978) and others. These lines set the boundaries between low (no action needed), continue sampling and high categories (Initiate control).

Computation of the decision lines (d1 and d2) for negative binomial distribution is represented by the formulae follows:

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$$d1 = Sn + h1$$

$$d2 = Sn + h2$$

where n = number of samples

S is the slope of the line

$$S = K \frac{\log \frac{q2}{q1}}{\log \frac{[p2q1]}{[p1q2]}};$$

where,

$$P1 = \frac{m1}{k} ; \qquad P2 = \frac{m2}{k}$$

$$q1 = 1 + p1; \qquad q2 = 1 + p2$$

m1 and m2 are class limits or economic threshold levels.

The 'm' values were assumed as 25 hoppers /hill and 20 hoppers /hill for without predators and with predator cases respectively and the levels 'm1' and 'm2' were set at 1/3 and 2/3 of the m. The 'm2' level corresponds to the economic threshold level at which treatment should be initiated to prevent economic damage.

K = dispersion parameter of the negative binomial distribution.

Parameter K was calculated by moments and regression method (Bliss, 1958; Bliss and Owen, 1958) using the formulae :

$$K = \frac{(\bar{x})^2 - S^2/N}{S^2 - \bar{x}}$$

Where $\bar{x}$ is mean and S^2 is variance and N is number of plants on which x is based

and h1 is the intercept of the lower line and is obtained by

$$h1 = \frac{\log B}{\log \frac{[p2q1]}{[p1q2]}} \qquad B = \frac{\beta}{1-\alpha};$$

while h2 is the intercept of the upper line and is given by

$$h2 = \frac{\log A}{\log \frac{[p2q1]}{[p1q2]}} \qquad A = \frac{1-\beta}{\alpha};$$

where α = the risk of calling a low infestation high

β = the risk of calling a high infestation low

Operating characteristic (OC) curve

The OC curve elpsh in predicting the chances of making a correct decision at various infestation levels. The OC curve for this sequential sampling gives the probability, L(p) of making a correct decision at different infestation levels of the insect. Thus L(p) is the probability of accepting m1 and m2 and P the population mean per sample. The OC curve was computed as per the following formulae

$$L(p) = \frac{A^h - 1}{A^h - B^h} \qquad \text{when } h \neq 0$$

$$P = \frac{1 - (q1/q2)^h}{(p2q1/p1q2)^h - 1}$$

When h is a dummy variable

Average sample number (ASN) curve

It indicates the average number of samples needed at various infestation levels for a particular plan. The average number of inspections required is given by

$$Ep(n) = \frac{h_2 + (h_1 - h_2)\, L(P)}{K.P - S}$$

Results and discussion

Sequential sampling plan

Sequential sampling plans for the rice BPH infestation were developed for all sets of data with a view to classify infestation levels as light, medium and severe, so as to initiate chemical control methods by inspecting minimum number of plant samples. Decision lines were worked out by individual field dispersion parameters 'K' ($\bar{x}2$ /S2-$\bar{x}$) and decision lines for overall season were developed by computing with common K (Kc) values i.e., 2.4667 in absence of the predators and 2.2351 in presence of the predators. The economic injury levels used were 25 hoppers/ plant and 20 hoppers/plant for with out and with predator cases, respectively. The decision lines for the two hypotheses 'to treat' and 'not to treat' the crop were worked out by taking the two levels of infestation as light and severe as given in Table 1.

The numerical values of lower and upper limits of sequential sampling plans for overall season and the decision lines of the same (Figure 1) that could be used for taking on the spot decision with respect to control measures of the rice BPH using the following procedure.

If ten plants are sampled randomly and cumulative BPH count is found to be less than 93, the decision of not spraying will be taken. But if the cumulative count is more than 137, then the decision of spraying should be taken. If the cumulative BPH count falls between 93 to 137, continue taking more samples and even after thirteenth sample decision is to still continue sampling, then the decision to treat will be taken. In case of fields considering predator counts, random samples are to be taken and the number of hoppers and number of predators on the sample plant are to be recorded. For calculating, the cumulative totals and the number of BPH are to be adjusted by subtracting five hoppers for each major predator found (Shepard and Ferrer, 1990). After calculating the adjusted cumulative total, sampling procedure can be carried out as in the earlier case. Similar sequential sampling plan for insect pests were developed by Hodgson *et al*., (2004) and Patrick *et al*., (2004).

Operating characteristic (OC) curve

The values of L(P) and P were calculated (Table 2) and the curves were depicted for overall season plan in Fig. 2. From Table 2, it can be observed that when mean population is 3.2432 the probability of labelling the infestation as light is 0.95. Hence the probability of labelling it as severe is 0.05. If mean is 6.8918 the probability of labelling the infestation as light was 0.05 and the probability of labelling it as severe was 0.95. Similar conclusions can be made from with predator case when mean populations are 3.1318 and 5.8163, respectively. Thus, with the help of sequential sampling the probability of taking a right decision for rating the infestation is 95 per cent. Therefore a sequential sampling plan for the rice BPH as found in the investigation could be considered as accurate and quite effective.

Table 1. The decision lines for light versus severe (1/3 EIL Vs 2/3 EIL) infestation

Field No.	d1 (Lower limit)	d2 (Upper limit)
1	11.4930n - 20.4665	11.4930 n + 20.4665
1a	9.4392n - 28.1931	9.4392 n + 28.1931
2	11.5765n - 11.3457	11.5765 n + 11.3457
3	11.5649n - 12.0838	11.5649 n + 12.0838
4	11.5080n - 17.8761	11.5080 n + 17.8761
5	11.4567n - 31.5675	11.4567 n + 31.5675
6	11.4951n - 20.0654	11.4951 n + 20.0654
6a	9.4438n - 25.8670	9.4438 n + 25.8670
7	11.4826n - 22.7605	11.4826 n + 22.7605
7a	9.4479n -24.0898	9.4479 n + 24.0898
S	11.4854n - 22.0946	11.4854 n + 22.0946
Sa	9.4460n - 24.8583	9.4460 n + 24.8583

S = Overall season; a = Field with predators

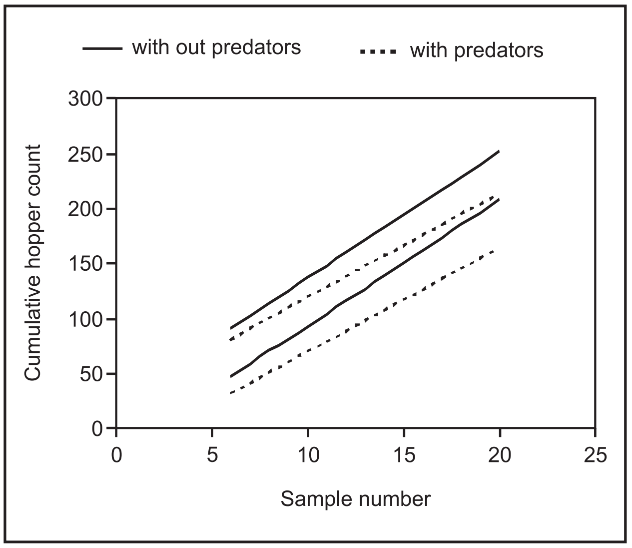

Figure 1. Sequential sampling plan for overall season

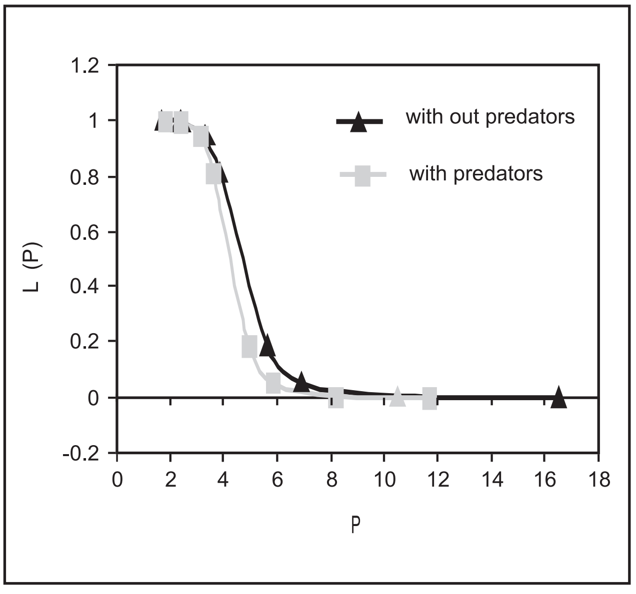

Figure 2. Operative characteristic curve

Average sample number curve

The average sample number function can be used to determine the average number of samples, which must be considered at different infestation stages. The average sample number curves for the light Versus severe infestation at $\alpha = \beta = 0.05$ are illustrated graphically for the overall season in Figure 3 based on the results presented in Table 3. For the overall season (with out predators), when mean P = 2.3276 corresponding to light infestation level, the average sample number was 3.8253 and at P = 10.5105 corresponding to severe infestation, the average sample number was 1.5215. Therefore, it can be inferred that at light or severe infestation levels, very few samples are required for taking a decision with regard to using chemical control measures but moderate infestation requires more number of samples.

Table 2. Rice BPH infestation (P) and the probabilty L(P) at different values of h

Value of 'h'	Value L(P)	Over all season with out Predator P	Overall season with Predators P
α	α	0.0000	0.0000
3	0.9998	1.7183	1.8217
2	0.9972	2.3276	2.3664
1	0.9500	3.2432	3.1318
½	0.8134	3.8712	3.6292
-1/2	0.1866	5.6432	4.9457
-1	0.0500	6.8918	5.8163
-2	0.0027	10.5105	8.1615
-3	1.4577E-4	16.4879	11.6683
- α	0.0000	α	α

Table 3. Average sample number EP(n) at various values of rice BPH infestation

Value	Overall season without predator		Over all season with predators	
'h'	P	EP(N)	P	EP(N)
α	0.0000	α	0.0000	α
3	1.7183	3.0479	1.8217	4.6239
2	2.3276	3.8253	2.3664	5.9469
1	3.2432	5.7052	3.1318	9.1465
1/2	3.8712	7.1524	3.6292	11.6764
-1/2	5.6432	5.6878	4.9457	9.6881
-1	6.8918	3.6059	5.8163	6.2950
-2	10.5105	1.5215	8.1615	2.8105
-3	16.4879	0.7568	11.6683	1.4940
- α	α	0.0000	α	0.0000

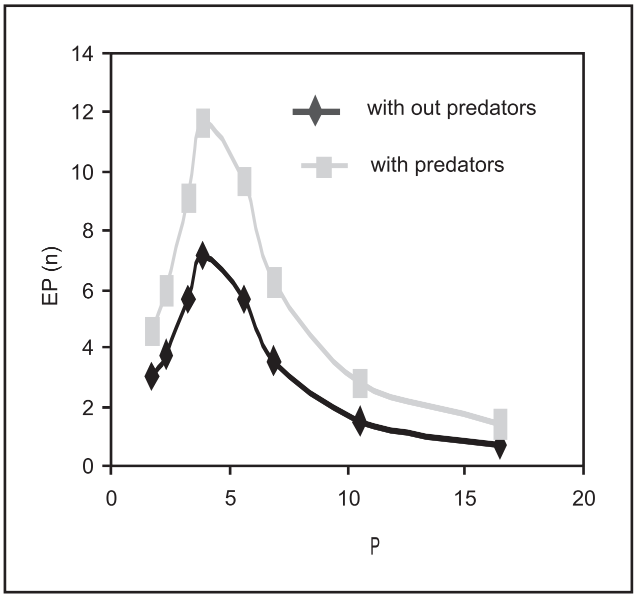

Figure 3. Averge sample number curve

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