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Sequential Sampling Technique for Decision Making in the Management of Cotton Aphids: *Aphids gossypii* Glover

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Abstract: A study was conducted in 2002 to examine the notable feature of sequential sampling plan and its efficiency in terms of number of observations of cotton aphids: *Aphids gossypii* Glover required to reach treatment decisions. The average number will be appreciably less under sequential sampling plan when operating with a fixed sample size. Sequential sampling plan based on the Negative Binomial Distribution (NBD) with common $K_c = 5.4278$, economic threshold level of lower limit $m_0 = 5$ aphids per plant and upper limit of $m_1 = 6$ aphids per plant and a risk factors α and β were set at 0.10 level was developed for using in the control of Cotton Aphids: *Aphids gossypii* Glover. In addition Operative Characteristic (OC) and Average Sample Number (ASN) curves were studied for predicting the probable number of samples required for different population densities. Results here suggest that the average number of aphids will be appreciably less under Sequential Sampling to make a treatment decisions. The shape of the OC curve depicts the behaviour of the sampling plan.

Key words: *Aphids gossypii* Glover, economic threshold, pest management, sequential sampling plan, operating characteristic curve, average sample number

Introduction

The dynamics of insect pest and the impact of the management system on commercial village forms were investigated over several years. Aphids are a serious pest of many crops including cotton. Aphids are pest because their feeding reduces the vitality of the crops. It is commonly known as the green aphids and it is widely distributed and is normally considered to be a minor pest of cotton but sometimes it does considerable damage. Aphids are wide distribution and have been regarded from all the cotton growing areas in India. The control theme of Integrated Pest Management (IPM) is that no single strategy of pest control is likely to achieve adequate results itself. Control can only be achieved by integrating a variety of approaches.

The concept of the pest control should be based on economic as well as ecological considerations has been a pervasive force in integrated pest management over the fast four decades (Stern *et al*., 1950; Stern, 1973; Pedigo and Higley, 1992). The economic threshold is the operational pest density that triggers a remedial action, such as spraying and insecticide, to prevent damage that

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Table 1: Statistical parameters for cotton Aphids: *Aphids gossypii* Glover in indigenous variety Rajath 2000

Standard month	No. of samples	Mean x	Variance S^2
September 8-14	25	7.28	20.8420
15-21	25	8.64	26.4700
22-28	25	10.44	8.7261
29- Oct. 4	25	4.76	6.6626
5-11	25	5.80	13.3598
12-18	25	13.44	55.5263
19-25	25	5.76	10.7427
26- Nov. 2	25	13.92	66.8731
3-9	25	11.04	28.8380
10-16	25	7.75	13.4374
17-23	25	8.00	10.2400

would exceed the cost of control. Conceptual and mathematical approaches for directly incorporating natural enemies into pest economic thresholds have been outlined (Frerier, 1994; Brown, 1997), but there are very few operational examples. More explicit recognition of natural enemies as integral components of pest suppression within decision-based management programmes is needed. To examine conservation of natural enemies within the context of an existing IPM frame work that bases insecticide use strictly on pest population densities (Naranjo *et al*., 2002).

For insecticides to be successfully integrated with other control measures, it is important to obtain precise population estimates by sampling. The sequential sampling methods may reduce sampling time by more than 50% (Water, 1955). The sequential decision plan is intended for use in practical control programmes where treatment decisions are being made, while the sequential counting plan is intended for use as a research tool for estimating population levels for research purposes. Developing an IPM programme is a difficult because any forming system has many interacting components. Rosenberg (1982) argues that any such system will be subject to considerable learning by using. This implies that benefits will increase as the degree of on-farm use increases. IPM is an improving technology with respect to yield and revenue if learning experiences add to the general knowledge base benefits from use will increase as more farmers adopt (Hall, 1977). Thus a study comprising these aspects was conducted.

Materials and Methods

Non-IPM of the indigenous variety “Rajath 2000” was planted in Gopichettipalayam, Erode District, Tamil Nadu, India in the year 2002 in 0.3 ha, spacing of 75×30 cm. The numbers of sucking pest per plant were observed by using a stratified random sampling technique. Twenty five plants were selected from the field on each week from 8th September to 23rd November, 2002. The data on original counts were arranged in frequency distribution and the spatial distribution pattern of the cotton aphids population was fitted quite well by Negative Binomial Distribution (NBD) (Table 1) (Subramaniam, 2004).

Results and Discussion

Before any particular sampling can be proposed, two kinds of parameters need to be determined. The first group of parameters are those that desirable distribution of the population to be sampled. The parameters might include the mean and variance of normally distributed population, the Kc, the common parameter of a population with a negative binomial distribution.

The knowledge of dispersion parameter common Kc is necessary for the development of sequential sampling plan for insect populations whose spatial distribution can be described by the NBD model (Water, 1955). In this study the dispersion parameter common Kc of NBD was obtained by Bliss (1958) and Bliss and Owen (1958).
The required formulae are:

$$X' = \overline{X} - \frac{S^2}{n}$$, Where n is number of samples

$$Y' = S^2\overline{X}$$

$$K' = \frac{\sum X'}{\sum Y'}$$

$$A = \frac{0.5(n-1)K'^4}{K'(K'+1)-(2K'-1)/n-3/n^2}$$

$$W = \frac{A}{X'(\overline{X}+K')^2}$$

$$Kc = \frac{\sum WX'^2}{\sum WX'Y'}$$

and

The common K_C of NBD was found to be 5.4278 for different sets of data.

In the present study, the economic threshold of lower limit, m_0 = 5 Aphids per plant and upper limits, m_1 = 6 Aphids per plant. Two class limit or simple hypothesis were used to control a Sequential Probability Ratio Test (SPRT) and two types of errors can occur in making decisions-accepting the null hypothesis (control is not needed) when the alternative hypothesis (control is needed) is true; and accepting the alternative hypothesis when the null hypothesis is true. The acceptable probability of these errors α and β, respectively must be specified in advance according to the perceived seriousness of error. Therefore, in this plan both types of errors α and β were set at 0.10 levels. For a NBD, a mean is μ and the variance is

$$\frac{\mu(\mu+K)}{\mu}$$

To determine whether the mean μ falls above or below a threshold, μ_t required for the initiation of measures to reduce insect numbers. In this connection the two simple hypothesis Ho: μ = 5 Vs H_1: μ = 6 were tested by taking α = 0.10, the probability of initiating a control programme when it is needed and β = 0.10, the probability of failing to initiate control programme when it is not needed. When the plants were selected sequentially at random, the population of interest and on each plants the number of aphids, x_i is recorded. After each plant is sampled a decision is made to stop and initiate a control programme, to stop but take no control measures or to continue sampling. The decision rule derived by Okland (1950), Wald (1945) and Morris (1954) is:

if
- $\Sigma x_i \le (h_0 + sn)$, stop sampling and take no control measures,
- $\Sigma x_i \ge (h_1 + sn)$, stop sampling and initiate control measures,
- $h_0 + sn < \Sigma xi < h_1 + sn$, continue sampling.

Where Σx_i is cumulative sums of Cotton Aphids and the intercepts were obtained as follows:

$$ho = \frac{\log B}{\log\left(\frac{p_1 q_0}{p_0 q_1}\right)}$$

$$h_1 = \frac{\log A}{\log\left(\frac{p_1 q_0}{p_0 q_1}\right)}$$

and

$$s = \frac{K \log\left(\frac{q_1}{q_0}\right)}{\log\left(\frac{p_1 q_0}{p_0 q_1}\right)}$$

The decision boundaries for the cotton aphids based on the sequential probability ratio test under NBD with common Kc = 5.4278 become.

$\sum x_i \le -23.533 + 5.4846n$, stop but take no control measure,
$\sum x_i \ge 23.533+5.4846n$, stop and initiate control measure.

These two equations may be used to determine the upper and lower limits for any number of samples (Fig. 1). Random samples are drawn in succession and cumulative cotton aphids population is estimated. They are to be checked against the (Table 2) values after every unit has been selected. Sampling is to be continued till a point wherein the cumulative number of cotton aphids fall either below the lower line or above the upper line. Accordingly a decision for pest control could be taken for aphids infestation, $\sum x_i$ is less than or equal to 4, then go further sampling and take a decision for not treating the crop. On the other hand $\sum x_i$ is greater than or equal to 51 then take a decision for treating the crop. But for the present case, the cumulative number of cotton aphids lies in between 4 and 51 and hence continues with sampling till a decision could be made.

The OC curve is presenting in Fig. 2 the horizontal axis displays the mean level of infestation (m) and the vertical axis, the probability of acceptance L(P) of making a correct decision at the various infestation levels. Wald's OC equation is given by the parametric equation.

$$L(P) = \frac{(A^h - 1)}{(A^h - B^h)}, h \ne 0$$

Where,

$$A = \frac{(1-\beta)}{\alpha},$$

and

$$B = \frac{\beta}{(1-\alpha)}$$

Table 2: Sequential sampling table for treatment decisions

	Cumulative cotton aphids	
No. of samples drawn	Lower limit	Upper limit
1	-	29
2	-	35
3	-	40
4	-	46
5	4	51
6	9	57
7	15	62
8	20	68
9	26	73
10	31	79
11	37	84
12	42	90
13	48	95
14	53	101
15	59	106
16	64	112
17	70	117
18	75	123
19	81	128
20	86	134
21	92	139
22	97	145
23	103	150
24	108	156
25	114	161

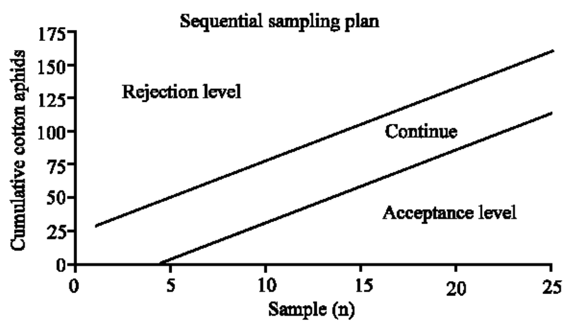

Fig. 1: Sequential sampling for cotton aphids: *Aphids gossypii* Glover

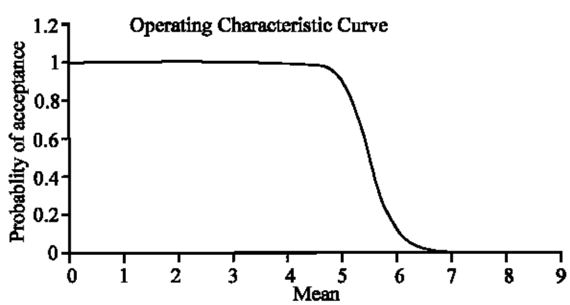

Fig. 2: Operating Characteristic (OC) curve

Table 3: Mean number of cotton aphids (m), the probability (L (p)) and the average sample number E (n) at different levels of h

h	P	Probability L (P)	Mean m = KP	ASN E(n)
	0.0000	1.00000	0.0000	4
2.00	0.8377	0.98780	4.5469	25
1.50	0.8779	0.96430	4.7651	30
1.00	0.9201	0.89990	4.9940	38
0.50	0.9643	0.74990	5.2340	47
-0.5	1.0592	0.24990	5.7490	45
-1.0	1.1101	0.09990	6.0254	35
-1.5	1.1635	0.03570	6.3152	21
-2.0	1.2194	0.01220	6.6187	20
-2.50	1.2780	0.00410	6.9367	16
-3.0	1.3395	0.00140	7.2705	13
-3.5	1.4039	0.00046	7.6201	11
-4.0	1.4714	0.00015	7.9865	9

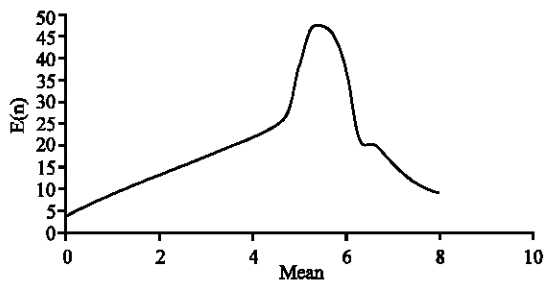

Fig. 3: Average Sample Number (ASN)

Using the OC function of the test, it is possible, to depict the behavior of the sampling plan. For example, when the mean number of infested plant was 4.9941, the probability of accepting the lower limit (Ho) and not recommending the treatment is 0.8999 and the probability of error is 0.10. As the infestation levels below 4.9941 or increase above 6.0254, the probability of error in accepting lower limit (Ho) becomes progressively lower. The notable feature of the plan is its efficiency in terms of number of observations required to reach decisions. The average number will be appreciably less under sequential sampling plan when operating with a fixed sample size.

ASN equation or curve shows, the average number of observations needed to make a terminating decision. The shape of the OC and ASN curves depend upon the underlying distribution and the class limits and their associated error probabilities. Efficiency for a sequential sampling scheme is measured by the ASN required for a given α and β. The number of samples needed when the following sequential sampling scheme may vary from trial to trial and the ASN represents the average of what might happen over many trials with a fixed incoming defect level. Wald's ASN function is:

$$E(n) = \frac{h_1 + (h_0 - h_1)L(P)}{KP - s}$$

Where:

$$P = \frac{1 - \left(\frac{q_0}{q_1}\right)^h}{\left(\frac{p_1 q_0}{p_0 q_1}\right)^h - 1}$$

For various values of P and L (P), average sample numbers were calculated and are presented in Table 3.

As it is seen from Table 3 and Fig. 3, the ASN was low at lower infestation level and increases with the increase in cotton aphids up to certain limit, it started decreasing with the further increase in cotton aphids. This showed that at high and low levels of cotton aphids, very few samples were required, whereas at intermediate more number of samples were required to be drawn.

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