Annals of Plant and Soil Research 22(1): 41-45(2020)

Distribution pattern and sequential sampling plan for shoot and fruit borer on okra (*Abelmoschus esculentus* L.)

UZMA MANZOOR[1], MASARRAT HASEEB[2] AND SUBHASH CHANDER[3]

Department of Plant Protection, Aligarh Muslim University, Aligarh-202002, India

Received: September, 2019; Revised accepted: November, 2019

ABSTRACT

A field experiment was carried out at Aligarh Muslim University, Aligarh (Uttar Pradesh) to study the distribution pattern and sequential sampling for shoot and fruit borer on okra during the summer season of 2013 and 2014. Spatial distribution of shoot and fruit borer, Earias vitella (Fabricius) (Lepidoptera: Noctuidae) on Arka Anamika variety of okra (Abelmoschus esculentus L.)was analyzed through Taylor's power law and Iwao's mean crowding regression. Taylor's power law showed regular distribution of this pest on okra in 2013 while as the distribution was aggregated in 2014 and on the basis of pooled data, Iwao's patchiness regression revealed aggregated distribution pattern of the pest. Based on the Taylor's power law parameters, the decision lines of sequential sampling for E. vitella were determined to be $d = 5.3n \pm 2.958\sqrt{n}$. *The sequential sampling plan would economize decision making for an effective management of E.vitella. At least 50% reduction in sampling effort could be expected through sequential sampling. Besides, economic injury level inclusive sequential sampling plan would be helpful in avoiding unwarranted pesticide application against E. vitella in okra.*

Key words: *Earias vitella*, okra, shoot and fruit borer, sequential sampling, spatial distribution.

INTRODUCTION

Among the vegetable crops, Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop grown especially in tropical and sub-tropical regions. It has occupied a prominent position in India among the export oriented vegetables because of its high nutritive value, palatability and good post harvest life. It has enormous potential as one of the foreign exchange earner crops and accounts for a major share in the production globally. Insect pest infestation is one of the most limiting factors for accelerating the yield potential of many vegetables including okra. Among the insect pests, shoot and fruit borer, *Earias vitella* is quite serious causing huge losses each year and is reported to cause damage to the extent of 3.5-90% in different parts of the country (Mandal *et al.* 2006a). The larvae of the pest bore into top shoots in the initial stages of infestation, which subsequently wither and droop. With the appearance of buds, flowers and fruits, these also are bored; the buds and flowers droop down whereas the fruits become stunted in growth and sometimes deformed in shape. Spatial distribution is one of the most characteristic properties of insect population; in most cases it allows us to define them. It is not fixed for insect populations but dynamic. It is important to find spatial and temporal structures in populations for applied and fundamental reasons. No field sampling can be efficient without understanding the underlying spatial distribution. Therefore, for efficient insect pest control, we need to know the dispersal pattern of insects in the region so as to define the hot spots of the infestation and modulate the dose of pesticides. It also gives information on theoretical population biology. With insects we postulate that populations also exist, that they are structured in space and in time and also genetically. So inorder to find how these limits vary during the life history of the insects we must find their spatial limits. Cost effective integrated pest management decisions need methods to estimate the insect density precisely and determine whether the density or infestation level has reached a threshold to take control measures. Sequential sampling is one of the most useful methods used to estimate insect population counts for faster management decisions (Darbemamieh *et al.* 2012). In comparison with other techniques, the savings in time and labour usually exceed 50 per cent (Parajulee *et al.* 2006; Rajna and Chander 2013). The present study was, thus, undertaken to analyze the distribution pattern of *E. vitella* and to develop sequential sampling plan.

Department of Agricultural Sciences, Sharda University, Greater Noida-201310, India
Department of Plant Production, Aligarh Muslim University, Aligarh-202002, India
Division of Entomology, IARI, New Delhi-110012, India
Corresponding author email: uzmamanzoor52@gmail.com

MATERIALS AND METHODS

The present study was carried out at the experimental field of Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh during kharif 2013 and 2014 on okra variety, Arka Anamica. All the recommended agronomic practices were followed to raise the crop, except plant protection measures which enabled the build-up of pests and their natural enemies in pesticide free environment. The shoot and fruit borer larval density was recorded by counting all the larvae in 5 randomly selected fruits/plot. The observation was carried out at weekly intervals. Larvae were either present inside the fruit or crawled on the fruits. Mean (X) and variance (S^2) of the population were determined for each sample during both the years. Variance (S^2) to mean (X) ratio was computed, wherein the value of (S^2/X) < 1, =1 and < 1 indicates uniform, random and an aggregated dispersion, respectively. The mean crowding was calculated as described by Southwood (1978):

$$X^* = X + (S^2/X)-1$$

Taylor's power law (Taylor 1961) depicted the variance (S^2) of a population to be proportional to mean density (X) such as

$$S^2 = a X^b$$

Where a = sampling parameter and b = aggregation parameter, which is considered as constant for a species. The value of regression coefficient, (b) = 1, >1 and <1 indicated random, regular and aggregated distribution of the pest species, respectively.

Iwao's mean crowding regression (Iwao 1968) related mean crowding (X*) with mean density (X) and could be expressed as

$$X^* = \alpha + \beta X$$

whereα = index of basic contagion and β = density contagiousness coefficient. The value of β=1 represents random, β< 1 regular and β> 1 aggregated distribution.

The optimum sample size (n) was calculated based on a and b parameters of Taylor's power law to develop the enumerative sampling plan with precision levels of 0.10 and 0.20 (Green 1970; Southwood 1978).

$$n = a X^b / C^2 X^2$$

Where a, b and X are as above; C = desired precision level.

The formulation of sequential sampling plan requires information on spatial distribution pattern and economic injury level of the pest on the crop (Kao 1984; Chander and Singh 2001). Sequential sampling plan for *E.vitella* was devised using Taylor's power law according to Ekborm (1985)

$d = nm_o \pm t (\sqrt{n}\ a\ m_o^b)$

$d_1 = nm_o + t (\sqrt{n}\ a\ m_o^b)$ and $d_0 = nm_o - t (\sqrt{n}\ a\ m_o^b)$ indicates the upper and lower decision lines of sequential sampling, respectively

d_0 = lower limit of the confidence interval for the cumulative number of *E.vitella*

d_1= upper limit of the confidence interval for the cumulative number of *E. vitella*

n = number of sample units observed

m_0 = Economic injury level of *E. vitella*

t = Student's t test at 20 per cent probability level

a = sampling parameter of Taylor's power law

b = aggregation parameter of Taylor's power law

The economic injury level of *Earias* species on okra is reported to be 5.3% damage (Krishnaiah *et al.* 1978). The maximum number of samples that would be required if the cumulative number of larval population remained between the upper and lower limits was expressed as:

$n_{max} = t^2 * a\ m_o^b / p^2$ where p ='t. Sx' (t = value of normal deviate and Sx = Standard error, SE of the mean). The SE of 25% of the mean was deemed as acceptable (Southwood and Henderson 2000). The value of t=1.28 at the probability level of 20%.

RESULTS AND DISCUSSION

In most of the samples during 2013, the variance to mean ratio (S^2/X) was found to be less than 1 indicating a regular distribution but the values tended towards randomness. In 2014, the S^2/X ratio was more than 1, indicating aggregated distribution behavior of *E. vitella* (Table 1 and 2).

Table 1: Mean, variance and variance-mean ratio of different samples of *E.vitella* for the year 2013 and 2014

2013			2014		
Mean(X)	Variance(S^2)	Variance-mean ratio (S^2/X)	Mean(X)	Variance(S^2)	Variance-mean ratio (S^2/X)
0.08	0.07	0.87	0.18	0.19	1.05
0.10	0.07	0.70	0.24	0.22	0.91
0.26	0.27	1.03	0.42	0.49	1.16
0.34	0.27	0.79	0.48	0.58	1.20
0.46	0.41	0.89	0.58	0.61	1.05
0.62	0.68	1.09	0.62	0.81	1.30
0.76	0.76	1.00	0.66	0.73	1.10
0.44	0.33	0.75	0.70	0.66	0.99
0.42	0.28	0.66	0.64	0.68	1.06
0.32	0.22	0.68	0.48	0.58	1.20
0.18	0.23	1.27	0.24	0.22	0.91
0.1	0.13	1.3	0.12	0.10	0.83
0.06	0.05	0.83	0.1	0.13	1.30

Variance to mean ratio is an important parameter in the spatial distribution pattern of an insect. *E. vitella* in 2013, showed a distribution which tended towards randomness. This pattern of dispersion is characterized by lack of any strong social interaction between species. *E. vitella* in the year 2014 showed aggregated distribution. It may be due to the inability of the young ones to move independently from their habitat and such mechanism also acts against predation.

Table 2: Parameters of Taylor's power law for fruit and shoot borer, *E. vitella* infestation in okra

Crop season	Sample size	Sampling parameter (a)	Aggregation parameter (b)	R^2
2013	13	1.17	0.943	0.93
2014	13	1.12	1.028	0.96
pooled	26	1.00	1.005	0.93

Taylor's Power law equations for *E. vitella* were $\log S^2 = 0.943 \log X - 0.069$ ($R^2 = 0.930$) for 2013

$\log S^2 = 1.028 \log X + 0.05$ ($R^2 = 0.967$) for 2014
$\log S^2 = 1.005 \log X + 0.004$ ($R^2 = 0.939$) for pooled data of two years

Iwao's mean crowding regression equations for *E. vitella* were

$X^* = 1.158X - 0.201$ ($R^2 = 0.700$) for 2013
$X^* = 1.084X + 0.035$ ($R^2 = 0.700$) for 2014
$X^* = 1.248X - 0.131$ ($R^2 = 0.679$) for the pooled data of two years.

Taylor's power law for the year 2014 and Iwao's patchiness regression showed aggregation distribution of *E. vitella* in okra field during 2013, 2014 and the pooled data for both the years (Table 3 and 4).

Table 3: Parameters of Iwao's mean crowding for fruit and shoot borer, *E. vitella* infestation in okra

Crop season	Sample size	Index of basic contagious-ness (α)	Density contagiousness coeffecient (β)	R^2
2013	13	0.201	1.158	0.70
2014	13	0.035	1.084	0.70
pooled	26	0.131	1.248	0.67

However, for 2013, the Taylor's power law showed the distribution tending towards randomness. The randomness of *E. vitella* can be attributed to the fact that when population in any area becomes sparse, the chance of an individual occurring in any sampling unit is so low that the distribution in effect becomes random. The results of the present studies are supported by the findings of Mazed*et al.* (2016) who reported aggregated distribution of *E. vitella* in okra field. Dispersion is an important characteristic of population that affects spatial patterns of resource use and population effect on community and ecosystem attributes. Aggregated dispersion results from grouping behaviour or restriction to particular habitat patches. Aggregation is typical of species for enhancement of resource exploitation or protection of predators. Dispersion pattern can change during insect development, during change in population density or across spatial scales. Many host specific insects are aggregated on particular hosts in diverse communities but are more regularly or randomly dispersed in more homogenous communities dominated by hosts (Tedim *et al.*, 2014).

Table 4: Optimum sample size at 10% and 20% precision level for shoot and fruit borer, *E. vitella* in okra

Mean incidence	Optimum sample size at 10% precision	Optimum sample size at 20% precision	Sampling number	Mean incidence	Optimum sample size at 10% precision	Optimum sample size at 20% precision
0.08	1234.28	308.57	14	0.18	550.77	137.69
0.1	988.55	247.13	15	0.24	413.62	103.40
0.26	382.01	95.50	16	0.42	235.41	58.85
0.34	292.52	73.13	17	0.48	207.54	51.88
0.46	216.5	54.13	18	0.58	171.92	42.97
0.62	160.90	40.22	19	0.62	160.90	40.22
0.76	129.82	32.45	20	0.66	151.18	37.79
0.44	226.32	56.57	21	0.70	142.60	35.65
0.42	237.04	59.25	22	0.64	155.89	38.97
0.32	310.67	77.67	23	0.48	207.54	51.88
0.18	549.89	137.47	24	0.24	413.62	103.40
0.1	988.55	247.13	25	0.12	824.51	206.12
0.06	1643.20	410.80	26	0.1	988.55	247.13

To achieve 10 and 20% precision levels in density estimates, quite a large number of samples were required as shown in table 5. An optimum sample size ranged from 130 to 1643 at various mean densities, while for 20% precision, it ranged from 33 to 308. Based on Taylor's power law spatial distribution parameters *viz.*, aggregation parameter (b=1.005) and sampling parameter (a=1), EIL as 5.3% and tolerable error in decision as 20% (t= 1.28), the decision lines of sequential sampling for *E. vitella* were determined to be

$d = 5.3n \pm 2.958 \sqrt{n}$

Lower decision line, $d_o = 5.3n - 2.958\sqrt{n}$
Upper decision line, $d_1 = 5.3n + 2.958\sqrt{n}$

Table 5: Decision lines for sequential sampling for shoot and fruit borer, *E. vitella* incidence on okra

Lower decision line $d_o = 5.3n - 2.985 \sqrt{n}$	Upper decision line $d_1 = 5.3n + 2.985 \sqrt{n}$	Sampling number	Lower decision line $d_o = 5.3n - 2.985 \sqrt{n}$	Upper decision line $d_1 = 5.3n + 2.985 \sqrt{n}$
2.3	8.2	14	63.0	85.2
6.4	14.7	15	67.9	90.9
10.8	21.0	16	72.9	96.6
15.2	27.1	17	77.8	102.3
19.8	33.1	18	82.7	107.9
24.5	39	19	87.7	113.5
29.2	44.9	20	92.6	119.2
33.9	50.7	21	97.6	124.8
38.7	56.5	22	102.6	130.4
43.6	62.3	23	107.5	136.0
48.4	68.1	24	112.5	141.6
53.2	73.8	25	117.5	147.2
58.2	79.5	26	122.5	152.8

These equations are used to find the upper and lower limits of pest infestation for any number of samples. For instance, if 3 picked fruits are observed for larval infestation and cumulative number of larvae found is less than 11 then decision not to spray has to be taken and if the cumulative number of larvae happen to be more than 21 then decision to spray is to be taken. However, if the cumulative number of larvae lies between 11 and 21, then more samples have to be taken until a decision of either to spray or not spray is arrived at.In case of indecisiveness, the maximum number of samples to be observed in sequential plan at 20% probability was found to be 9. It means that if any decision is not reached after observing 9 samples then decision to spray is to be taken. Decision making is an important aspect of integrated pest management programme and will continue to play a key role (Shankar and Abrol, 2012). In order to determine an appropriate time to assess population densities and apply management options sampling is important. The sampling objective can be to classify the population into categories such as ‘intervention needed’ and ‘intervention not needed’ or to achieve a particular precision of the mean pest density (Lomic, 2001). The sequential sampling is very economical for management decisions compared to random sampling (Chander, 2012). It minimizes the number of samples required to achieve a desired sampling objective. Sequential sampling plans achieve low sample sizes by taking into consideration only minimum number of samples required to reach a decision (Chander, 2012). At least 50% reduction in sampling effort could be expected through sequential sampling as observed by Carleton *et al.* (2013). Besides, economic injury level inclusive sequential sampling plan would be helpful in avoiding unwarranted pesticide application against *E. vitella* in okra.

ACKNOWLEDGEMENTS

Authors are grateful to Department of Science and Technology, New Delhi for financial assistance in the form of Inspire Fellowship and Head, Department of Plant Protection for providing necessary facilities to carry out this work.

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