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A negative binomial distribution for describing pattern of green stink bug in pigeon pea crop after spraying insecticides

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ABSTRACT

This paper deals with the application of negative binomial distribution for describing the inherent variability in the number of green stink bug on pigeon pea in experimental field. The low yields of pigeon pea crop are due to green stink bug. The parameters of negative binomial distribution areestimated by the method of Method of Moments (MM) and Method of Proportion of Zeroth Cell (MPZC). In order to test the suitability of the distribution, values have been computed and seemed to be non- significant.

***Keywords*:** Estimation, method of moments, MPZC, negative binomial distribution, parameters

Historically, India is the largest producer, consumer and importer of pulses. The top producer of pulses in India is Madhya Pradesh, as it contributes 24% of the overall pulses production of the nation. Other major pulse producing states include Rajasthan and Uttar Pradesh (Anon., 2013-14). As they serve a low-cost protein to meet the needs of the large section of the people, they have, therefore, been justifiably described as the poor man's meat. In general, pulses contain 20 to 25 percent protein and 60 percent carbohydrate with the exception of soybean, which has as much as 43.2 percent and 20.9 percent, respectively (Anon., 2012-13). Pulses are also fairly good sources of thiamin and niacin and provide calcium, phosphorus and iron. On an average 100 g of pulses contain 345 kcal energy, protein 24.5 g, calcium 140 mg, phosphorus 300 mg, thiamin 0.5 mg, riboflavin 0.3 mg and niacin 2 mg (Singh *et al*.,2002).

Pigeon pea, *Cajanus cajan* (L.) is known by more than 350 dialect names, the crop ranks fourth in importance as edible legume in the world. It is the second most important pulse crop after chick pea in India (Das *et al*., 2015). Pigeon pea is mainly grown as marginal or a component of mixed cropping system in cotton, sorghum and soybean, receiving less attention of farmer (Sharma *et al*., 2011). Mandal *et al*. (2009) observed that pigeon pea was infested with as many as 21 insect- pest and two species of mites as different stages of crop growth in an overlapping manner. Climate change may lead to shift in production areas of the pigeon pea as well as changes in geographical distribution, incidence and intensity of pest and diseases. The efficacy of different newer insecticides action against pod fly and pod borer on long duration pigeon pea variety "Bahar" (Keval *et al*., 2016).

Pigeon pea is the second important pulse crop of India which has diversified uses as food, feed, fodder and fuel. Pigeon pea popularly known as *arhar*, *tur*, red gram, congo pea, noneye pea etc. and occupies an area of about 3.8 mha with production of 3.02 million tonnes and yield of 776 kg ha^{-1} in India (Anon., 2013-14). It is a rich source of protein (21.71%) and supplies a major share of protein requirement of the vegetarian population of the country. It is a rich source of iron, iodine and essential amino acids like arginine, cysteine and lysine.

In Madhya Pradesh, it is cultivated in an area of 0.5305 million ha with a total production of 0.351 million tonnes and yield of 662 kg ha^{-1}. A large number of insect pests have been identified to infest pigeon pea.

The elementary distribution such as binomial, Poisson and negative binomial may describe the pattern of pest population where mean is larger to variance,equal to variance and smaller to variance respectively. A number of distributions have been devised for series in which the variance is significantly larger than the mean,frequently on the basis of more or less complexed biological phenomenon (Bliss and Fisher,1953). Sometimes the behavior of pest population can be described by contagious distribution. In such situation, attempts would be made to propose or derive other distribution for knowing their clustering pattern or grouping pattern to a large class of biological data. The main objective of the present research is to study the occurrence pattern of the green stink bug on pigeon pea crop so that the spray of insecticides can be utilized in time.

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MATERIALS AND METHODS

The data were gathered from an experimental field of Department of Entomology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), during *Kharif* season 2014-15. The sowing of pigeonpea (TJT-501) was performed on 4th July 2014, having row to row distance 0.6 m, plot to plot distance 0.2 m and plot size 10 × 12m, following a randomized complete block design (RCBD) with 14 treatments and 3 replications. The recommended fertilizer dose of 18:46:00 kg ha^{-1} (N: P: K) were applied respectively. Onehand weeding was done at 30 DAS. In order to study the spatial pattern of occurrence of major insect pest (Green stink bug) on pigeon pea crop was observed on which a negative binomial distribution was fitted by estimating it's parameters by method of moment (MM) and method of proportion of zero'th cell (MPZC).

Negative binomial distribution

The pattern of dispersion of plants, animal or insect population is an important aspect of its population biology because it is a result of the interaction between individual of the species and their habitat. When individual disperse over an area, they tend to have greater concentration in some areas rather than that of others. This aggregation or clustering behavior may be due to social instincts, mode of egg laying or competition for food and space, etc. To describe this quantitatively, negative binomial distribution which belong to the family of contagious distribution, has been extensively used by Nayak and Reddy, 1987; Peng and Brever, 1994; Sardana,1996; and Gour, 1997.

The equality of the mean and variance is an important property of the Poisson distribution, whereas for the binomial distribution the mean is always greater than the variance. Occasionally, however observable phenomena give rise to empirical distribution, which consist of variance larger than the mean that results negative binomial discrete probability distribution. It has been shown through different investigations that negative binomial distribution provides an excellent model when the distribution has a variance larger than the mean. For example, bacterial clustering (or contagion) death of insect, number of insect bites, lead to the negative binomial distribution. This has beengeneralized andmodified (or inflated) in numerous ways. The modified form of the distribution had described the data under study of various investigations. In this context, Sharma (1988) had applied two inflated probability distribution to another sets of data and found that these distributions described the data well rather than original ones.

Let X denote the number of major insect pest (Green stink bug) on pigeon pea plant. The distribution of X derived under the following assumptions:

(i) The number of major insect pest on pigeon pea occur in groups, the number of groups Y(the insect always move with their family is called groups), follow a Poisson distribution with parameter, θ

$$P[y = 1] = \frac{e^{-0}\theta^{1}}{j^{1}}, \; \theta > 0 \text{ and } j = 1, 2, 3 ....(1)$$

(ii) The number of individual (insect) per group has the logarithmic series distribution,

$$P = [z = k] = \frac{\lambda^{k}}{k[-\log(1-2)]}, \; k = 1,2,3, ... (2)$$

Under the above assumptions, the distribution of X (green string bug) is the probability that there is a total of k individual (insect) with the coefficient of t^k in

$$\sum_{j=0}^{\infty}\left[\frac{e^{-0}\theta^{1}}{j!}\right]\left[-\alpha \log(1-\lambda t)\right]^{1} = e^{-\theta-\alpha\log(1-\lambda t)}$$

$= e^{-\theta(1-\lambda t)^{-\alpha\theta}}$

$= (1-\lambda t) / (1-\lambda)^{\alpha\theta}$

where, $\alpha = -[\log(1-\lambda t)]^{-1}$

This probability is therefore,

$$P=[x=k]=\frac{[(\alpha\theta+k)}{K![\alpha\theta}(1-\lambda)^{-\alpha\theta}\lambda^{k}$$

$$P=[x=k]=\binom{\theta+k-1}{k-1}(1-\lambda)^{-\alpha\theta}\lambda^{k} ....(3)$$

The equation (3) is complicated from the point of view of its estimation of parameters,therefore we have put this equation in the simplified form by letting $\lambda = q$ and $\alpha\theta = r$. Hence

$$P = [x = k] = \binom{r+k-1}{r-1}p^{r}q^{k} .... (4)$$

Estimation

The above negative binomial distribution consists of two parameter p and r. These were estimated by two methods namely method of moments and the method of proportion of zeroth cell.

Method of moments

In this method these two parameters are estimated by equating the observed mean, observed variance with their corresponding theoretical value. These are given below:

$\mu_1 = \frac{rq}{p}$, $\mu_2 = \frac{rq}{p^2}$, where and are the sample mean and sample variance of the observed data.

Method of proportion of zerothcell

In this method, the observed proportion of zeroth cell is n_0/N where n_0 and N are frequency of zero'th cell and total frequency respectively.

$m_1 = \frac{rq}{p}$, where m_1 is the sample mean.

RESULTS AND DISCUSSION

Table 1 gives the distribution of observed and expected number of sites according to the number of green stink bug on the observation recorded from 30/ 11/2014. The distribution was fitted by two method *i.e.* method of proportion of zeroth cell, method of moments. The estimates of two parameters p and r by two methods were found to be 0.69, 0.68, 0.91, and 0.90, respectively. The estimates of p and r by the method of MM and MPZC were slightly different from each other. For applying a test, some last cells were grouped together. The values of $\div^2$ were 0.36 and 0.40 respectively. The values of $\div^2$ at 5% level of significance and 1 degrees of freedom are found to be non-significant.

Table 2 gives the distribution of observed and expected number of sites according to the number of green stink bug on the observation recorded from 02/ 12/2014.The distribution was fitted by two method *i.e*. method of proportion of zeroth cell, method of moments. The estimates of two parameters p and r by two methods were found to be 0.60, 0.61, 064, and 0.70, respectively. The estimates of p and rby the method of MM and MPZC were slightly different from each other. For applying a test, some last cells were grouped together. The values of $\div^2$ were 2.84 and 2.71 respectively. The values of $\div^2$ at 5% level of significance and 1degrees of freedom are found to be non-significant.

Table 3 gives the distribution of observed and expected number of sites according to the number of green stink bug on the observation recorded from 06/ 12/2014.The distribution was fitted by two method i.e. method of proportion of zeroth cell, method of moments. The estimates of two parameters p and r by two methods were found to be 0.63, 0.68, 0.84, and 0.96, respectively. The estimates of p and rby the method of MM and MPZC were slightly different from each other. For applying a test, some last cells were grouped together. The values of $\div^2$ were 2.31 and 4.31 respectively. The values of $\div^2$ at 5% level of significance and 1 degrees of freedom are found to be non-significant

Table 4 gives the distribution of observed and expected number of sites according to the number of green stink bug on the observation recorded from 09/ 12/2014.The distribution was fitted by two method i.e. method of proportion of zeroth cell, method of moments. The estimates of two parameters p and r by two methods were found to be 0.63, 0.73, 0.64, and 0.91, respectively. The estimates of p and r by the method of MM and MPZC were slightly different from each other. For applying a test, some last cells were grouped together. The values of $\div^2$were 0.66 and 4.0 respectively. The values of $\div^2$ at 5% level of significance and 1degrees of freedom are found to be non-significant.

Table 1: Distribution of observed and expected number of pigeon pea plants according to number of green stink bug on the observations recorded on 30/11/2014 after spraying

Negative binomial distribution			
No. of insect/plant	Observed	Expected	
		MM	MPZC
0	149	150.20	149.26
1	45	42.15	42.57
2	11	12.38	12.67
3	3	3.9	3.82
4	1	1.11	1.16
5	1	0.47	0.52
	$\hat{p}$	0.69	0.68
	$\hat{r}$	0.91	0.90
	χ^2	0.36	0.40
	d.f	1	1

Table 2: Distribution of observed and expected number of pigeon pea plants according to number of green stink bug on the observations recorded on 02/12/2014 after spraying

Negative binomial distribution			
No. of insect/plant	**Observed**	**Expected**	
		MM	**MPZC**
0	149	151.11	148.92
1	45	39.01	40.44
2	8	12.79	13.34
3	5	4.49	4.66
4	1	1.63	1.67
5	2	0.98	0.97
	$\hat{p}$	0.60	0.61
	$\hat{r}$	0.64	0.70
	χ^2	2.84	2.71
	d.f	1	1

Table 3: Distribution of observed and expected number of pigeon pea plants according to number of green stink bug on the observations recorded on 06/12/2014 after spraying

Negative binomial distribution			
No. of insect/plant	**Observed**	**Expected**	
		MM	**MPZC**
0	145	143.50	146.71
1	43	44.00	43.66
2	11	14.72	13.48
3	8	5.06	4.21
4	3	2.72	1.94
	$\hat{p}$	0.63	0.68
	$\hat{r}$	0.84	0.96
	χ^2	2.31	4.31
	d.f	1	1

Table 4: Distribution of observed and expected number of pigeon pea plants according to number of green stink bug on the observations recorded on 09/12/2014 after spraying

Negative binomial distribution			
No. of insect/plant	**Observed**	**Expected**	
		MM	**MPZC**
0	158	156.18	157.70
1	34	37.05	38.75
2	11	11.24	9.99
3	5	3.66	2.62
4	2	1.87	0.94
	$\hat{p}$	0.63	0.73
	$\hat{r}$	0.64	0.91
	χ^2	0.66	4.00
	d.f	1	1

The negative binomial distribution described the pattern of the number of Green stink bug and after first, second and third spray of the insecticides.The method of moments was found to be better estimation procedure than method of proportion of zeroth cell in the fitting of negative binomial distribution for estimating the parameters of the model.

The spray of insecticides during first week of December was found to be more effective to keep the crop free from Green sting bug as by fitting of negative binomial distribution with parameters p and r.

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