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On probability models for describing population dynamics of major insect pests under rice-potato-okra cropping system

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ABSTRACT

In the present investigation, trends in population dynamics of major insect pests under rice-potato-okra cropping system have been studied through probability models. Among the major insect pests climbing cutworms were observed on rice, whiteflies and jassids on potato and whiteflies, aphids and jassids on okra. The data have been taken from an experiment which was conducted by the staff of department of Agronomy during kharif, Rabi and summer season 2006-07 at the Krishi Nagar farm, Adhartal JNKVV, Jabalpur, following randomized complete block design (RCBD) with varying number of treatments under each crop. The variety pusa basmati was taken for rice, kufri jawahar for potato and ladies finger for summer okra. The occurrences of the insects were grouped in the form of frequency distribution according to the number of plants. The Poisson distribution is found to be adequate for describing the pattern of climbing cutworms on rice, whiteflies and jassids on potato and aphids on okra. In addition to these, Polya-Aeppli distribution is well fitted for the number of whiteflies and jassids on okra. These distributions may be used for forecasting of the losses in these crops due to major insect pests considered here.

Keywords**:** Insect pests, population dynamics, probability models, rice-potato-okra cropping system

Any realistic model of a real-world phenomenon must take into account the possibility of randomness. That is, the variables in which we are interested will exhibit an inherent variation that should be taken into account by the model. This is usually accomplished by allowing the model to be probabilistic in nature. Such a model is naturally enough referred to as a probability model. It is of the two types (i) deterministic and (ii) stochastic. In a deterministic model we use 'physical considerations' to predict the outcome while in a probabilistic model we use the same kind of considerations to specify a probability distribution. A probabilistic model describes the situation more accurately in comparison to deterministic model. In order to check the validity of the model, we must deduce a number of consequences of our model and then compare these predicted results with observations.

In recent years, the changes in cropping system as well as the propagation of diversification and intensification in agriculture have attracted the increasing attention of scientists, biologist, and entomologist to study about the insect pest problem. In India, pests damage all kinds of crops leading to worth rupees of lacs every year. In order to study this problem, plant protection measures are of recent one, otherwise indiscriminate and unwise application of pesticides world certainly result in a large number of serious ill effect. A large number of studies have been dealt with various aspects of aphids on cereals, oilseeds, pulse and vegetable crops. But none of the study has been done so far on the population fluctuation of major insect pest under cropping system alongwith their management practices. The trends of dispersion of climbing cutworms, whiteflies, jassids, aphids etc. under natural condition are important aspects of their population biology because they are the result of interaction between individuals of species and their habitats.

One aspect of interest of pattern of dispersion in regard to major insect population is to observe the aggregation or clustering or grouping pattern, which may be, because of social instinct, mode of egg laying or competition for food and shelter etc.

The elementary distributions such as binomial, Poisson, logarithmic, negative binomial, geometric may describe the pattern of pest population. Sometimes, the behavior of pest population can be described by contagious distribution. In such situation, attempts would be made to propose and derive the other distribution for knowing their clustering pattern to a large class of biological data.

MATERIALS AND METHODS

In order to study the spatial pattern of occurrence of climbing cutworms, whiteflies, jassids and aphids through Poisson and Polya-Aeppli distribution, their methods of estimation of the parameters and impact of different treatments considered here on yield and the

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occurrence of number of climbing cutworms, whiteflies, Jassids and aphids, the data were taken from an experiment. These experiments had been conducted to meet out the routine objective of the experiment on Rice–Potato–Okra Cropping System

The sowing of rice cv. pusa basmati was performed on 26th June, 2006 in nursery and 27th July, 2006 in transplanting having row to row distance of 25cm, plant to plant 15 cm in crop and seed treated with thiarum of 0.2% solution, following of RCBD with 10 treatments and 3 replications. The plot size was 13x11 m. The rice crops were harvested on 30th October, 2006, respectively. The data on occurrence of climbing cutworm were gathered since the incidence of pest. In the experiment ten treatments were considered with three replications, each replication comprised of 10 random plants for observations. In this way, in each treatment 30 plants were selected randomly and tagged for the recording of the number of climbing cutworm and their other aspects. Thus, overall 300 plants were selected each time and the data were recorded daily starting from 14th October-2006 on hills of each selected plant.

The sowing of potato cv. Kufri Jawahar, was performed on 7th November 2006 having row to row distance of 60 cm, plant to plant 25 cm in crop and seed treated with Diftiane M-45 of 0.2% solution following of RCBD with 8 treatments and one replication. The plot size was gross 35x6 m and net 34x4 m. The potato crop was pitted on 25th February, 2007. The data on occurrence of whiteflies and jassids were gathered since the incidence of pest. In the experiment eight treatments were considered with one replication, each treatment comprised of 10 plants for observations. In this way, in each treatment 10 plants were selected randomly and tagged for the recording of the number of white flies & jassids and their other aspects. Thus, overall 80 plants were selected for each insect in each time and the data were recorded daily starting from 8th December, 2006 on each selected plant.

The sowing of okra was performed on 1st march, 2007 having row to row distance of 50 cm, plant to plant 15 cm in crop and seed treated with Thiarum of 2.5g. kg^{-1} seed, following of RCBD with three treatments and one replication. The plot size was 14x18 m. The picking was started on 23rd, May 2007. The data on occurrence of whiteflies, aphids and jassids were gathered since the incidence of pest. In the experiment three treatments were considered with one replication, each treatment comprised of 10 plants for observations. In this way, in each treatment 10 plants were selected randomly and tagged for the recording of the number of whiteflies, jassids and aphids and their other aspects. Thus, overall 30 plants were selected for each insect in each time and the data were recorded daily started from 21st March, 2007 on each selected plant.

In order to study the occurrence of climbing cutworm, white fly, Jassids and aphids on rice-potato-okra cropping system, the number of individual insects was counted daily on each plant. The original counts were then summarized in the form of frequency distribution showing the number of plants containing x=0,1,2,3… climbing cutworm, white fly, jassids and aphids of a given species. If each plant were exposed equally to the chance of containing the climbing cutworms, whiteflies, jassids and aphids during the study period, the probable probability distributions would be Poisson and Polya-Aeppli distribution.

In recent years, the Poisson, distribution has been used to way markedly increasing extent, but reasons underline its use are, in the great majority of cases. Like the binomial distribution, Poisson distribution, often serves as a standard form. A random variable x is said to have a Poisson distribution with parameter λ if its probability mass function is given by

$$P[x = k] = \frac{e^{-\lambda}, \lambda^{k}}{k!}, \ k = 0,1,2\ldots\ldots\ldots$$
$$0, \text{otherwise}$$

Estimation of parameters

This distribution contains one parameters λ. It is estimated by method of proportion of zero cells and method of moments.

(i) Method of proportion of zeroth cell (MPZC)

It is estimated by equating proportion of zero cell with their corresponding theoretical values

$$\text{(i.e.)} \frac{n_0}{N} = e^{-\lambda} \text{and } \lambda = -\text{In}\left(\frac{n_0}{N}\right)$$

(ii) Method of moments

The parameter λ in Poisson distribution is estimating by method of moments which is given below:

λ = mean of the original distribution

Poisson distribution is fully discussed by Johnson and Kotz (1969).

Description of spatial spread of white fly and jassids of okra crop was of considerable importance.

When individual white fly and jassids dispersed over an area, they tended to have greater concentration in some areas rather than others. One aspect of interest of dispersion pattern of white fly and jassids population was to study aggregation or clustering pattern, which might be due to social instinct, mode of egg laying or competition for food and space etc. In order to observe the pattern of white fly and jassids quantitatively, Sarada *et al.* (2001) applied Polya-Aeppli distribution to the data on onion thrips (*Thrips tabaci* L.) as were reported by Srinivasan *et al.* (1981).

This distribution is one of the important contagious distribution and is useful for the situation where events (which are to be counted) occur in clusters and the number of clusters follows a Poisson distribution with expectation q and the number of individuals (white fly and aphids) per cluster follows a geometric distribution with parameter q. It had been applied to the number of plants per quadrat to the ecological data and not to the number of white fly and jassids per plant especially on okra crop. The situation in the process of observing the number of white fly and jassids per plant is similar to the above. The spatial spread of white fly and jassids per plant can be described by this distribution. For completeness, this distribution is defined by

$$P_k = P[X = k] = e^{-\theta} p^k \sum_{j=1}^{k} \begin{bmatrix} k=1 \\ j=1 \end{bmatrix} \frac{(\theta 1/p)^j}{j!}, (k \geq 1); 1 = 1 - p$$

Polya-Aeppli distribution was described by Polya (1931). He ascribed the derivation of the distribution of Aeppli (1924) in a thesis.

Estimation of parameters

This distribution consists of two parameters and q and these are estimated by two methods given below:

(i) Method of proportion of zero[th] cell

In this method, the observed proportion of zeroes (n_0/N) and sample mean (m1') are equated to their corresponding theoretical values. It is given below:

$$e^{-\theta} = \frac{n_0}{N} \text{ and } m_1' = \frac{\theta}{q}$$

The parameters q and q were estimated from the above relationships

$$\text{(i.e.) } \theta = -\text{In}\left(\frac{n_0}{N}\right), q = \frac{\theta}{m_1'}$$

(ii) Method of moments

In this method, these two parameters were estimated by equating the observed mean and observed variance with their corresponding theoretical values. It is given below:

$$m_1' = \frac{\theta}{q}, m_2 = \frac{\theta(1+p)}{q^2}$$

where, m1' and m2 are the sample mean and sample variance of observed data respectively (Johnson and Kotz, 1969).

In order to compare Polya-Aeppli distribution, negative binomial distribution is utilized whose probability mass function is given by

$$P[X = x] = \binom{x+r-1}{r-1} p^r q^x, \quad \begin{matrix} x = 0,1,2,\ldots\ldots\ldots \\ p+q=1 \end{matrix}$$

This distribution consist of two parameters r, p and q whose estimates are determined by method of moments.

The mean and variance of negative binomial distribution are rq/p and rq/p^2 respectively.

RESULTS AND DISCUSSION

The proposed model was fitted for the number of climbing cutworm on paddy crop, white fly & jassids on potato crop and whiteflies, aphids and jassids on okra crop for the varying number of treatments.The adequacy of Poisson distribution was advocated on the pooled data of various numbers of treatments.

Table 1: Distribution of observed and expected number of plants according to number of climbing cutworm of rice crop.

No of climbing cutworm	Observed frequency	Poisson distribution	
		MPZC	MM
0	317	317.00	323.83
1	211	202.25	199.71
2	60	64.52	61.58
3	10	13.72	12.66
4	1	2.19	1.95
5	1	0.31	0.27
Total	**600**	**600.00**	**600.00**
Estimate of		**λ = 0.64**	**λ = 0.62**
parameter	χ^2	**3.87**	**3.85**
	d.f.	**4**	**4**

Table-1 provides the distribution of observed and expected number of paddy plants according to number of climbing cutworm. The distribution was fitted by two methods i.e. method of proportion of zeroth cell and method of moments. The estimates of λ in the method MPZC and method of moments were found to be 0.64 and 0.62 respectively. The risk of occurrence of climbing cutworm on rice crop was almost in both methods. The values of c2 at respective degrees of freedom are found to be non-significant. For visual displayed the graphical representation of Poisson distribution using two methods MPZC and method of moments was exhibited in figure-1.

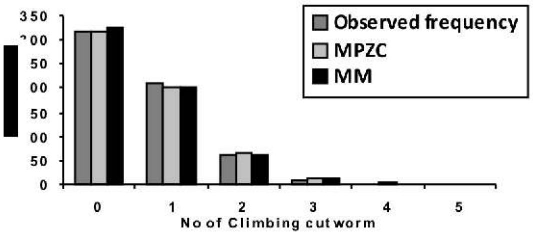

Fig. 1: Fitting of Poisson Distribution under MPZC and Method of MM cutwirm of rice crip

Table 2: Distribution of observed and expected number of plants according to number of white fly of potato crop

No. of potato white fly	Observed frequency	Poisson distribution	
		MPZC	MM
0	43	43.00	49.69
1	148	125.71	138.08
2	198	183.75	191.85
3	156	179.06	177.70
4	135	130.86	123.45
5	78	76.51	68.61
6	25	37.28	31.77
7	9	15.57	12.61
8	5	5.69	4.38
9	2	1.85	1.35
10	1	0.73	0.50
Total	**800**	**800.00**	**800.00**
Estimate of		**λ = 2.92**	**λ = 2.78**
parameter	χ^2	**15.20**	**10.21**
	d.f.	**9**	**9**

Table-2 provides the distribution of observed and expected number of potato plants according to number of white fly. The distribution was fitted by two methods i.e. method of proportion of zeroth cell and method of moments. The estimates of λ in the method MPZC and method of moments were found to be 2.92 and 2.78 respectively. The risk of occurrence of white fly on potato crop was almost in both methods. The values of c2 at respective degrees of freedom are found to be non-significant. For visual displayed the graphical representation of Poisson distribution using two methods MPZC and method of moments was exhibited in fig.-2.

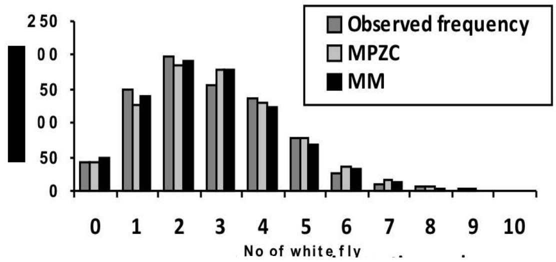

Fig. 2: Fitting of poisson Distribution under MPZC and MM for white fly of potato crop

Table 3: Distribution of observed and eexpected number of plants according to number of jassid of potato crop.

No of jassid	Observed frequency	Poisson distribution	
		MPZC	MM
0	445	445.00	460.41
1	278	261.01	254.38
2	69	76.55	70.27
3	6	14.97	12.94
4	2	2.48	2.00
Total	**800**	**800.00**	**800.00**
Estimate of		**λ = 0.59**	**λ = 0.55**
parameter	χ^2	**7.31**	**6.46**
	d.f.	**3**	**3**

Table-3 provides the distribution of observed and expected number of potato plants according to number of jassid. The distribution was fitted by two methods *i.e.* method of proportion of zeroth cell and method of moments. The estimates of λ in the method MPZC and method of moments were found to be 0.59 and 0.55 respectively. The risk of occurrence of jassid on potato crop was almost in both methods. The values of c2 at respective degrees of freedom are found to be non-significant. For visual displayed the graphical representation of Poisson distribution using two methods MPZC and method of moments was exhibited in fig.-3.

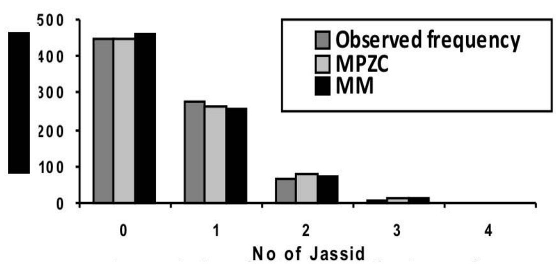

Fig. 3: Fitting of Poisson Distribution under MPZC and MM for Jassid of potato crop

Table 4: Distribution of observed and expected number of plants according to number of aphid of okra crop.

No. of potato white fly	Observed frequency	Poisson distribution MPZC	MM
0	124	124.00	118.65
1	95	96.49	97.56
2	31	37.54	40.11
3	15	9.74	10.99
4	5	2.23	2.69
Total	**270**	**270.00**	**270.00**
Estimate of		**λ = 0.78**	**λ = 0.82**
parameter	χ^2	**7.44**	**5.82**
	d.f.	**3**	**3**

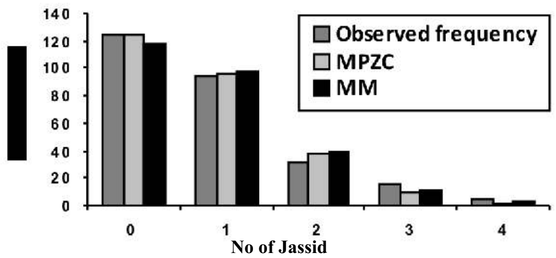

Fig. 4: Fitting of Poisson Distribution under MPZC and MM for Jassid of okra crop

Table 5: Distribution of observed and expected number of plants according to number of white fly of okra crop.

No. of white fly	Observed frequency	Polya-Aeppli Distribution MPZC	MM	Negative Binomial Distribution
0	62	62.00	59.55	55.94
1	63	58.64	59.45	63.13
2	46	48.67	49.86	51.62
3	34	36.03	36.88	36.86
4	18	24.72	25.12	24.42
5	16	16.04	16.11	15.41
6	14	9.98	9.87	9.41
7	11	6.00	5.82	5.61
8	6	7.92	7.34	7.60
Total	**270**	**270.00**	**270.00**	**270.00**
Estimate of		**θ=1.47**	**θ=1.52**	**r=2.23**
parameter		**q=0.64**	**q=0.66**	**p=0.49**
$\chi 2$		**8.68**	**9.43**	**10.96**
d.f.		**6**	**6**	**6**

Table-4 provides the distribution of observed and expected number of okra plants according to number of aphid. The distribution was fitted by two methods i.e. method of proportion of zeroth cell and method of moments. The estimates of λ in the method MPZC and method of moments were found to be 0.78 and 0.82 respectively. The risk of occurrence of aphid on okra crop was almost in both methods. The values of c2 at respective degrees of freedom are found to be non-significant. For visual displayed the graphical representation of Poisson distribution using two methods MPZC and method of moments was exhibited in fig.-4.

Table-5: gives the distribution of observed as expected number of okra plants according to number of whitefly of okra. For this insect Polya-Aeppli distribution was fitted by two methods, i.e. MPZC and method of moments and for comparison purpose, negative binomial distribution had also been supplemented. The estimates of q in method of MPZC was less than the MM whereas the pattern of q was also less. The values of c2 at respective degrees of freedom are found to be non-significant. For visual display, the graphical representation of this distribution using to method was given in fig.-5.

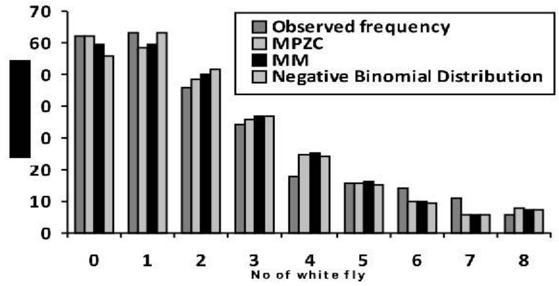

Fig. 5: Fitting of Polya-Aeply Distribution under pistribution for white fly of okra crop

Table 6: Distribution of observed and expected number of plants according to number of jassid of okra crop.

No. of jassid	Observed frequency	Polya-Aeppli Distribution MPZC	MM	Negative Binomial Distribution
0	51	51.00	43.57	43.52
1	84	88.65	88.43	88.47
2	83	86.85	93.18	93.23
3	64	62.76	67.83	67.82
4	51	37.15	38.30	38.27
5	17	19.03	17.87	17.85
6	10	14.57	10.83	10.84
Total	**360**	**360.00**	**360.00**	**360.00**
Estimate of		**θ=1.95**	**θ=2.11**	**r=27.16**
parameter		**q=0.89**	**q=0.96**	**p=0.93**
$\chi 2$		**7.25**	**7.13**	**7.18**
d.f.		**4**	**4**	**4**

Table-6 gives the distribution of observed as expected number of okra plants according to number of jassid of okra. For this insect Polya-Aeppli distribution was fitted by two methods, *i.e.* MPZC and method of moments and for comparison purpose, negative binomial distribution had also been supplemented. The estimates of q in method of MPZC was less than the MM whereas the pattern of q was also less. The values of c2 at respective degrees of freedom are found to be non-significant. For visual display, the graphical representation of this distribution using to method was given in fig.-6.

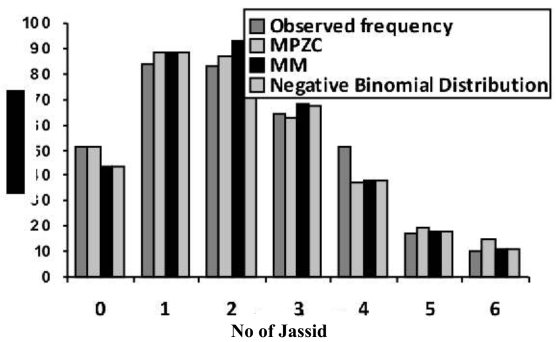

Fig. 6: Fitting of Polya-Aepty Diatribution under MPZC and MM compare with Nagative Binomial Distrbultion for jassid of okra crop

In this investigation, attempts have been concentrated to suggest adequate probability models which can describe the clustering pattern of climbing cutworm on rice, white flies, jassids on potato and white flies, jassids & aphids on okra. In order to identity the spatial pattern of their insect-pests under this cropping system, Poisson and Polya-Aeppli distributions were advocated under some realistic assumptions.

Polya-Aeppli distribution was considered to be suitable model for forecasting to describe the inherent variation of the white fly and jassids of okra. Similarly, Poisson distribution was found to be adequate model for predicting the variability of climbing cutworm of rice, white fly and jassids of potato and white fly, jassids and aphid of okra.

The method of proportion of zeroth cell was found to be better estimation procedure for estimating the parameters of the model rather than that of method of moments.

Therefore, these two models can be utilized for forecasting these insects on rice-potato-okra cropping system in future.

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