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Seasonal and spatial distribution pattern of pod borer in pigeonpea *Cajanus cajan* (L.)

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Abstract
The study has been undertaken to analyze spatial distribution pattern of pod borer of pigeonpea crop under Chhattisgarh plains of Chhattisgarh state. Spatial distribution of pod borer in pigeonpea crops, the various indices of dispersion, *viz*., variance mean ratio indicated that the pod borer in pigeonpea followed the regular distribution for all standard weeks, patchiness index indicated that the pod borer in pigeonpea followed the dispersed nature distribution for all standard weeks, Iwaos's m*-m relationship indicated that the population of pod borer in pigeonpea showed regular distribution, Taylor's power law indicated that the population of pod borer in pigeonpea had dispersed nature of distribution. Positive significant correlation with maximum temperature in 45th, 47th, 48th, 50th, 51th and 52th standard week, negative significant correlation with 46th, 49th, 1st, 2nd, 3rd and 4th standard week and rest standard weeks non-significant correlated, negative significant correlation with rainfall in 45th, 46th, 48th, 3rd and 4th standard week and rest standard weeks non-significant correlated, positive significant correlation with RH-I in 50^{th,} 52th, 1st, 2nd, 3rd and 4th standard week, negative significant correlation with 45th, 47th, 48th, 49th and 51th standard week and rest standard weeks non-significant correlated. On the basis the values of standard error, R^2 and R^2 (adjusted) in both regression model, it was found that model-B gives a better fit of transformed data the model-A of pod borer population. So, we may use model-B to predict the dynamics of pod borer population.

Keywords: Spatial distribution, regular distribution, contagious nature, dispersed nature, correlation, regression model, population dynamic

1. Introduction
Pigeonpea [*Cajanus cajan* (L.) Millsp] is considered as one of the most important legume crop of India. Pigeonpea belong to the family Fabaceae. Pigeonpea is commonly known as red gram, tur, arhar. Pigeonpea provides high quality vegetable protein to human beings and is one of the sources of animal feed and fire wood. In India, pigeonpea is grown in 3.86 million hectares with an annual production of 2.65 million tonnes and 741 kg ha^{-1} of productivity (FAOSTAT, 2012), which is 4/5th share in the world total pigeonpea produced. About 90% of the global pigeonpea area falls in India (Anon., 2012) [1]. In Chhattisgarh, acreage under pigeonpea is 51.9 thousand hectares with a total production and productivity of 31 thousand tonnes and 597 kg/ha, respectively (Anon., 2013) [2].
The important insects pests causes nearly 30% economic loss by attacking the crop at vegetative and reproductive stages by Pod borer (*Helicoverpa armigera*), Legume pod borer (*Maruca testulalis*), Pod fly (*Melanagromyza* spp.) are the major insect of pigeonpea in Chhattisgarh state.
Spatial distribution is one of the most important ecological properties of a species (Taylor, 1984) [11] and information on this aspect can serve as a basis for decision making to implement management strategies in the field (Bechinski and Pedigo, 1981) [4]. A primary requisite in better understanding of an organism in its ecosystem is knowledge of its spatial distribution pattern (Sevacherian and Stern, 1972) [8]. Insect population may follow the binomial (regular), random (Poisson) and negative binomial (aggregated) distribution pattern (Southwood, 1978) [9].

2. Materials and Methods
The study has been undertaken to analyse spatial distribution pattern of pod borer in pigeon pea crop under Chhattisgarh plains of Chhattisgarh state for one year *i.e.* 2015-2016. The proposed study of spatial distribution of pod borer in pigeon pea is based on primary and secondary data.

Pod borer population were observed at weekly interval on randomly selected ten plants from sowing to harvesting of the crop. The incidence of pod borer were recorded weekly during the pigeonpea growing season from July to febury in the year 2015-2016 along with weekly observations of meterological variables, *viz.*, temperature, (maximum and minimum), rainfall, relative humidity and sunshine. These observations were compiled according to weeks and recorded after taking weekly averages. To develop the forewarning model, the following techniques were used to know about the dynamics of insect pests in relation to time and meteorological variables. For the ease of analysis and findings, meteorological data were also pooled out at weekly interval. The data on infestation of various pests were correlated with prevailing temperature, relative humidity, sunshine hours and wind velocity obtained from observatory of the university and similarly correlated with insect pest population.

The various indices of dispersion to find out the distribution behaviour of pod borer in pigeonpea are given below as per the formulae given by Faleiro *et al.* (2006) [6], David and Moore (1954), Iwao's (1968) [7] and Taylor's Power Law

The regression of meteorological variables as independent variables in the cubic model was carried out. The following statistical models were used to know the dynamics of the population of pod borer:

ModelA. Log (Yi +1) = Xi = a + b t + c t^2 + d t^3 +e

ModelB. Log (Yi +1) = Xi = a + b t + c t^2 + d t^3 + b_1 (max.temp) + b_2 (min.temp) + b_3 (rainfall) + b_4 (relative humidity) + b_5 (sunshine) + e

Where i = 1, 2, 3, 4, 5 and t represents weeks and t = 1, 2… 20, a denotes intercept and b, c, d, b_1,b_2,b_3,b_4, and b_5 denote the regression coefficients of models A and B and e ~ N(0, σ^2). A (1-α)

Confidence interval for population build up for pod borer is $\hat{Y}_i \pm t\ \alpha/2,\ n\text{-}k\ x10^{s.e.}$, where $t\ \alpha/2,\ n\text{-}k$ is a tabulated value of t at α/2 level and $n\text{-}k$ degrees of freedom.

For pod borer, the two models described above, were fitted using a regression technique, and the values for regression coefficients, multiple correlation (R^2), adjusted multiple correlation (R^2) and standard error were calculated. The results for each insect pest are given in Equations (1) to (8), in which the asterisks ** and* denote the significance of terms in the models at 1 and 5% levels respectively.

3. Result and Discussion

3.1. Distribution behaviour of pod borer: The various indices of dispersion to find out the distribution behaviour of pod borer in pigeonpea are showed in table 1 and describe below.

3.1.1. Variance mean ratio

If the value of VMR is 1 there will be poisson distribution while less than 1 indicates for regular and more than one indicates for negative binomial distribution. Higher variance value over mean indicates that there is contagious or aggregate nature of distribution. In this study VMR indicated that the pod borer in pigeonpea followed the regular distribution for all standard weeks.

3.1.2. Exponent K

The parameter k is a valid measure of aggregation. Its value can range from 0, where aggregation is extreme to infinity that means a purely random distribution of counts. Any large value of k indicates an approach towards randomness and it also indicates the relative degree of aggregation for the condition involved. In this study exponent k indicated that the pod borer in pigeonpea followed the regular distribution for all weeks.

3.1.3. Mean crowding

If the value of mean crowding is greater than it's respective mean than it follows the negative binomial distribution. And if the value of mean crowding is less than it's respective mean than it follows the regular distribution. In this study mean crowding indicated that the pod borer in pigeonpea followed the regular distribution for all standard weeks.

3.1.4. Patchiness index

If the Patchiness value less than one, the distribution will be dispersed. When equal to one or more than one, the distribution of population will be random or clumped respectively.In this study patchiness index indicated that the pod borer in pigeonpea followed the dispersed nature distribution for all standard weeks.

3.1.5. David & Moore index

The index of clumping of David & Moore gives a value of zero for random population. Negative value for regular distribution and positive value shows contagious pattern of distribution. David and Moore index indicated that pod borer in pigeonpea followed the regular distribution for all standard weeks.

3.1.6. Iwao's m*-m relationship

If contagiousness coefficient is greater than one, indicate insect population followed negative binomial distribution, rather poisson or random distribution pattern.In graphical analysis of the data (Fig. 1.), it was found that contagiousness coefficient was less than one, which indicated that pod borer population followed regular distribution.

3.1.7. Taylor's power law

If 'b' equal to one, than the population has a random distribution and when b greater than one or less than one the population follow contagious (aggregated) or regular nature of distribution, respectively. The value of b in equation is less than one; this indicates that the entire pod borer population in pigeonpea is having dispersed nature of distribution (Fig.2).

3.2. Effect of weather parameters on population build- up of pod borer

Week wise range, mean, standard deviation and correlation of pod borer population are presented in table 2 and table 3. Positive significant correlation of pod borer population observed with maximum temperature in 45^{th}, $47^{th,}$ $48^{th,}$$50^{th}$, 51^{th} and 52^{th} standard week and observed negative significant correlation with 46^{th}, 49^{th}, 1^{st}, 2^{nd}, 3^{rd} and 4^{th} standard week and rest standard weeks non-significant correlated. Pod borer population showed positive significant correlation with minimum temperature in $45^{th,}$ $46^{th,}$ 47^{th}, 49^{th}, 50^{th} and 3^{rd} standard week and negative significant correlation with 48^{th}, 51^{th},52^{th}, 1^{st}, 2^{nd} and 4^{th} standard week and rest standard weeks non-significant correlated.

Positive significant correlation of pod borer population with RH-I observed in $50^{th,}$ 52^{th}, 1^{st}, 2^{nd}, 3^{rd} and 4^{th} standard week

and negative significant correlation observed in 45th, 47th, 48th, 49th and 51th standard week and rest standard weeks showed non-significant correlation. Positive significant correlation of pod borer population with RH-II in 49th, 50th, 51th, 3rd and 5th standard week and negative significant correlation observed in 45th, 46th, 47th, 48th, 52th, 1st, 2nd and 4th standard weeks and rest standard weeks showed non-significant correlation.

Pod borer population showed negative significant correlation with rainfall in 45th, 46th, 48th, 3rd and 4th standard week and rest standard weeks non-significant correlated. Positive significant correlation with sun shine hours observed in 45th, 46th, 47th, 48th, 51th, 52th, 1st, 2nd and 4th standard week while, negative significant correlation observed in 49th, 50th and 3rd standard week and rest standard weeks were non-significant correlated.

3.3. Forewarning models for forecasting of pod borer population in pigeonpea crop.

When the cubic model (A) was used, we got the following regression equation and values of standard error, multiple correlations, and adjusted multiple correlations (Table 4) :

Log (Pod borer+1) = $0.010 + 0.030t + 0.021t^2 - 0.002t^{3**}$

Standard error = 0.054, R^2 =0.954, R^2 (adj) =0.937 (1)

Model (B) was used and we obtained the following regression equation below along with standard error, multiple correlations, and adjusted multiple correlations (Table 5):

Log (Pod borer +1) = 0.161 - 0.005 (max.temp.) + 0.002 (min.temp.) - 0.003 (rainfall) - 0.001 (relative humidity) + 0.010 (sunshine) $+0.008\ t + 0.027t^2 - 0.002\ t^3$

Standard error =0.074, R^2 =0.967, R^2 (adj) = 0.880 (2)

We observed that equation (2) gives a better fit of the transformed data than equation (1) of pod borer. So we may use equation (2) to predict the dynamic of pod borer population.

Table 1: Different parameters of spatial distribution of pod borer in pigeonpea for the year 2015- 2016.

Standard Week	Mean	Variance	VMR	k-value	Mean Crowding	Patchiness Index	Iwao's	I_{DM}
45	0.23	0.04	0.19	-0.29	-0.58	-2.49	-0.81	-0.81
46	0.33	0.00	0.01	-0.34	-0.66	-1.97	-0.99	-0.99
47	0.50	0.01	0.02	-0.51	-0.48	-0.96	-0.98	-0.98
48	1.23	0.05	0.04	-1.29	0.28	0.22	-0.96	-0.96
49	1.97	0.01	0.01	-1.98	0.97	0.49	-0.99	-0.99
50	2.27	0.16	0.07	-2.44	1.34	0.59	-0.93	-0.93
51	3.00	0.09	0.03	-3.09	2.03	0.68	-0.97	-0.97
52	3.07	0.02	0.01	-3.09	2.07	0.68	-0.99	-0.99
1	3.00	0.04	0.01	-3.04	2.01	0.67	-0.99	-0.99
2	1.43	0.56	0.39	-2.36	0.83	0.58	-0.61	-0.61
3	0.53	0.08	0.16	-0.63	-0.31	-0.58	-0.84	-0.84
4	0.13	0.01	0.10	-0.15	-0.77	-5.75	-0.90	-0.90

Table 2: Standard week wise range, mean, standard deviation and correlation of weather parameters and pod borer population

Standard Week		Max T	Min T	Rainfall	RH-I	RH-II	SShr	Pod borer Population
45	Range	30.00-31.70	16.70-18.80	0.00-0.00	88-91	37-47	7.80-8.20	0.00-0.23
	Mean	34.35	17.70	0.00	90	42.67	7.93	0.08
	SD	0.85	1.05	0.00	1.73	5.13	0.23	0.13
	Correlation	0.61*	0.97*	-0.50	-0.28	-0.69*	0.38	
46	Range	27.50-31.70	16.30-33.20	0.00-0.00	84-91	36-45	6.80-7.60	0.00-0.33
	Mean	34.15	22.93	0.00	88	41.33	7.30	0.18
	SD	2.34	9.02	0.00	3.61	4.73	0.44	0.17
	Correlation	0.83*	-0.66*	-0.04	0.00	-0.89*	0.93*	
47	Range	29.30-30.60	11.90-16.70	0.00-0.00	87-91	28-40	7.30-8.50	0.10-0.50
	Mean	34.30	14.70	0.00	88.67	34.67	8.03	0.30
	SD	0.68	2.50	0.00	2.08	6.11	0.64	0.20
	Correlation	0.97*	0.95*	0.00	0.00	-0.87*	0.33	
48	Range	30.00-31.90	12.50-16.70	0.00-0.00	83-90	26-35	7.50-8.60	0.20-1.23
	Mean	35.03	14.93	0.00	86.67	31.67	8.17	0.61
	SD	1.04	2.18	0.00	3.51	4.93	0.59	0.55
	Correlation	0.99*	-0.08	-0.76*	-0.86*	-0.91*	0.89*	
49	Range	28.10-31.20	10.80-14.80	0.00-0.00	88-91	28-31	8.00-9.00	0.30-1.97
	Mean	34.30	12.47	0.00	89.67	30.00	8.50	0.96
	SD	1.61	2.08	0.00	1.53	1.73	0.50	0.89
	Correlation	-0.77*	0.95*	0.00	0.30	0.86*	-0.97*	
50	Range	27.70-30.10	9.80-17.30	0.00-4.40	77-90	27-49	3.00-9.00	0.50-2.27
	Mean	34.10	14.30	1.47	85.33	40.67	5.47	1.22
	SD	1.21	3.97	2.54	7.23	11.93	3.14	0.93
	Correlation	0.98*	0.98*	0.00	0.30	0.86*	-0.68*	
51	Range	25.00-28.10	8.30-16.60	0.00-9.40	85-90	31-52	3.00-8.00	0.80-3.00
	Mean	32.95	12.20	3.13	88.00	39.00	5.93	1.80
	SD	1.69	4.17	5.43	2.65	11.36	3.41	1.11
	Correlation	0.82*	-0.87*	0.00	-0.12	0.63*	0.04	
52	Range	26.00-28.30	9.90-12.70	0.00-0.00	86.93	29-40	6.20-8.30	2.30-3.00
	Mean	33.30	11.13	0.00	88.67	34.33	7.00	2.66

	SD	1.16	1.43	0.00	3.79	5.51	1.14	0.39
	Correlation	0.34	-0.12	0.00	0.12	-0.21	0.69*	
1	Range	25.00-30.50	12.10-14.80	0.00-9.40	82-95	27-52	4.50-7.90	3.00-3.90
	Mean	21.28	13.50	3.13	89	39.67	6.43	3.30
	SD	2.79	1.35	5.43	6.56	12.50	1.75	0.52
	Correlation	-0.41	-0.97*	0.00	0.82*	-0.99*	0.64*	
2	Range	25.80-29.30	8.00-14.10	0.00-29.30	87-90	27-47	5.40-9.20	1.43-4.00
	Mean	21.23	11.07	9.77	89	34.33	7.37	2.51
	SD	1.76	3.05	16.92	1.73	11.02	1.90	1.33
	Correlation	-0.50	-0.85*	0.00	0.43	-0.97*	0.96*	
3	Range	26.00-29.00	8.30-16.10	0.00-2.00	88-90	29-49	3.80-8.30	0.53-3.50
	Mean	21.35	12.90	0.67	89	41.33	5.57	1.84
	SD	1.50	4.08	1.15	1.00	10.79	2.40	1.51
	Correlation	-0.45	0.01	-0.75*	0.70*	0.32	-0.41	
4	Range	27.00-28.90	9.00-13.70	0.00-0.00	87-90	33.30-38.00	7.00-8.70	0.13-2.30
	Mean	22.03	12.07	0.00	88.33	36.10	7.70	0.91
	SD	0.96	2.66	0.00	1.53	2.48	0.89	1.21
	Correlation	-0.98*	-0.85*	-0.56*	0.39	-0.66*	0.53	

*Significant level at 5% (r=0.552)

SD = Standard deviation, RH = Relative humidity, SShr = sun shine hour, Max T = Maximum Temperature, Min T = Minimum Temperature.

Table 3: Association study of correlation between weather parameters and pod borer population in pigeon pea

Standard week	Max t	Min t	RF	RH I	RH II	SSH
45	Positive	Positive	Negative	Negative	Negative	Positive
46	Negative	Positive	Negative	--------	Negative	Positive
47	Positive	Positive	--------	Negative	Negative	Positive
48	Positive	Negative	Negative	Negative	Negative	Positive
49	Negative	Positive	--------	Negative	Positive	Negative
50	Positive	Positive	--------	Positive	Positive	Negative
51	Positive	Negative	--------	Negative	Positive	Positive
52	Positive	Negative	--------	Positive	Negative	Positive
1	Negative	Negative	--------	Positive	Negative	Positive
2	Negative	Negative	--------	Positive	Negative	Positive
3	Negative	Positive	Negative	Positive	Positive	Negative
4	Negative	Negative	Negative	Positive	Negative	Positive

---- insect population not found

Table 4: Statistical parameters of model A for pod borer population

Regression Statistics						
Multiple R			0.977			
R Square			0.954			
Adjusted R Square			0.937			
Standard Error			0.054			
Observations			12			
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	0.010	0.088	0.109	0.916	-0.192	0.211
t	0.030	0.056	0.540	0.604	-0.099	0.159
t^2	0.021	0.010	2.163	0.062	-0.001	0.044
t^3	-0.002	0.000	-3.998	0.004	-0.003	-0.001

Table 5: Statistical parameters of model B for pod borer population

Regression Statistics						
Multiple R				0.984		
R Square				0.967		
Adjusted R Square				0.880		
Standard Error				0.074		
Observations				12		
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	0.161	1.451	0.111	0.919	-4.457	4.779
Max.Temp.	-0.005	0.047	-0.104	0.924	-0.153	0.143
Min.Temp.	0.002	0.042	0.037	0.973	-0.132	0.135
RF	-0.003	0.003	-0.844	0.460	-0.013	0.007
RH	-0.001	0.010	-0.094	0.931	-0.032	0.030
SS	0.010	0.049	0.202	0.853	-0.146	0.166
t	0.008	0.085	0.094	0.931	-0.263	0.279
t^2	0.027	0.015	1.813	0.167	-0.020	0.074
t^3	-0.002	0.001	-2.849	0.065	-0.005	0.000

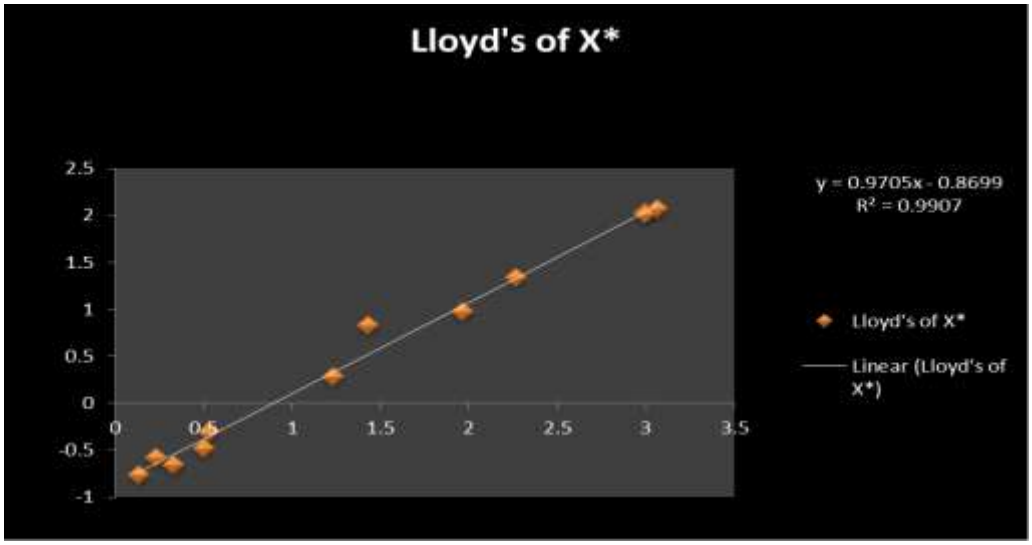

Fig 1: Relationship of mean density and Lloyd's mean crowding for pod borer of pigeon pea crop

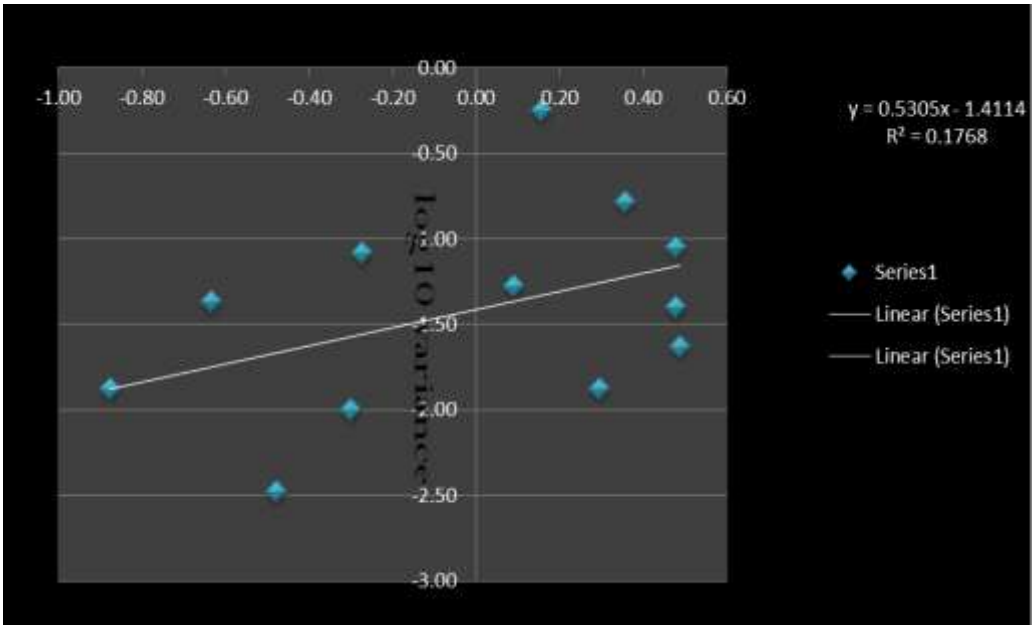

Fig 2: Taylor's power plots of pod borer in pigeonpea crop

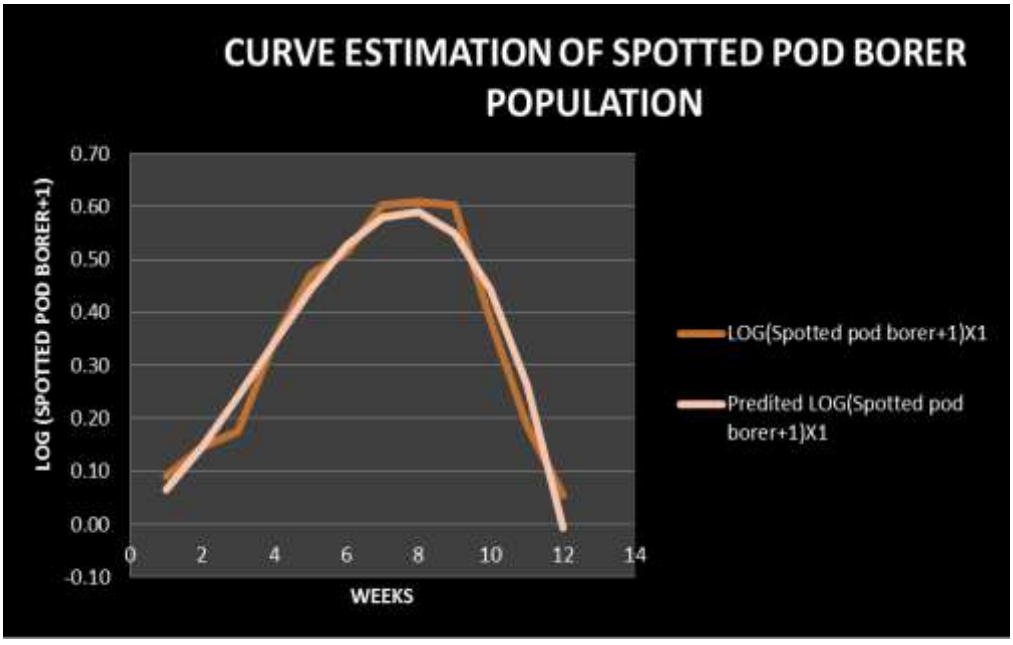

Fig 3: Curve estimation of pod borer for model A.

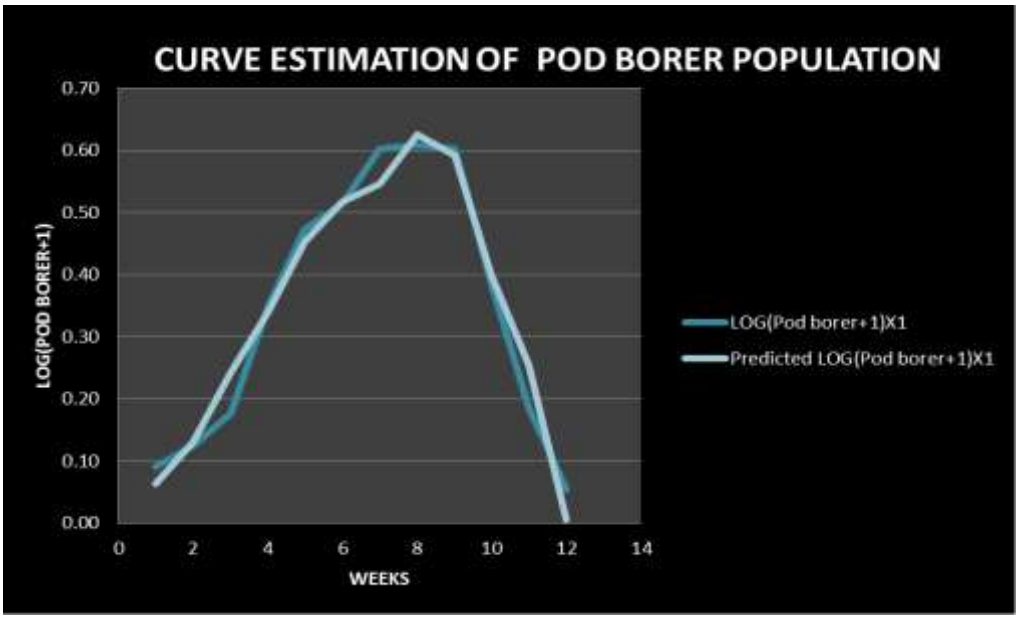

Fig 4: Curve estimation of pod borer for model B.

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