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Spatial Distribution of the Damage of Bud Worm, *Hendecasis duplifascialis* (Hampson) (Lepidoptera: Crambidae) on Jasmine, *Jasminum multiflorum*

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Abstract

The studies conducted on the spatial distribution of bud worm, *Hendecasis duplifascialis* on jasmine cv. *Jasminum multiflorum* at the farmer's field of Chandurayanahalli, Magadi taluk, Ramanagara district (Karnataka, India) indicated that the bud worm damage was found to be clumped or aggregated at different plant height interval. The damaged buds at different plant height intervals were related to the overall density of damaged buds in a plant. In both the cases, jasmine as monocrop and intercrop in coconut plantation, it was found that number of damaged buds at different height intervals was significantly and positively correlated with the total number of damaged buds in a plant. Further, the number of damaged buds present at 101-150 cm and 151-200 cm height intervals showed highly significant 'r' values with the total number of damaged buds in a plant in both monocropping and intercropping.

Keywords : Jasmine, Bud worm, *Hendecasis duplifascialis*, Spatial distribution

Jasmine is a highly valued commercial flower crop native to the tropical and subtropical regions of the world. It was introduced to South Asia in the mid sixteenth century (Pillai *et al*., 2016). It is being cultivated as ornamental plant in the home garden. It belongs to the family Oleaceae of the order Oleals and genus *Jasminum*. The genus *Jasminum* contains more than 200 species comprising both fragrant and non-fragrant flowers. In India, more than 82 species are being cultivated across the country. The commercial cultivation is confined to few states *viz*., Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Uttar Pradesh, Rajasthan and West Bengal. Tamil Nadu (Coimbatore, Thirunelveli, Madurai, Erode, Krishnagiri and Dindigul districts) is the leading producer of Jasmine in the country with an annual production of 77,247 tonnes in growing area of 9,360 ha (Prakash and Muniandi, 2014) and Karnataka (Bengaluru Rural, Ramanagara, Mysuru, Kolar, Tumakuru, Udupi, Chikmagalore, Kodagu, Davanagere, Uttara Kannada and Dakshina Kannada,Vijayanagara and Ballari districts) is the second highest producer of jasmine flowers with the annual production of 43,600 MT in growing area of 6,600 ha (Anonymous, 2014). The fresh flowers of jasmine are being exported to Malaysia, Singapore and Srilanka and Arab countries. Jasmine is one of the age old sweet scented flower crops cultivated with multipurpose utility. The buds and flowers are used for making garlands, hair adornments and for religious offerings. The flowers are used for the production of essential oils and attars (Arumugam *et al*., 2002).

Tropical climate conditions with well pulverized soil are ideal for jasmine cultivation. The ambient conditions like warm summer and humidity with adequate water supply and well drained sandy loam soils rich in organic matter with pH ranging from 6.0-7.5 are more suitable for jasmine cultivation. Commercial cultivation of jasmine in India is under open field conditions and distributed in the area where annual rainfall ranges from 800 to 1000 mm. The prominent species of jasmine that are commercially cultivated comprises *J. sambac, J. grandiflorum, J. auriculatum* in Tamil Nadu and *J. multiflorum* in Karnataka (Ganga and Lakshmi, 2017).

The *J. multiflorum* commonly called as star jasmine is an evergreen, twinning shrub with branching vine that can be trained. It is seen as open, spreading and weeping mound, 3-10 ft tall and just as wide. Flowers are borne in congested clusters at branch end and in small side shoots (Samata *et al*., 2019).

In Karnataka state, many small and marginal farmers grow jasmine for livelihood. Since from last one decade farmers are experiencing difficulty in cultivating jasmine due to few insect and mite pests, which were reported to cause considerable damage affecting flower production. The pests include budworm, *Hendecasis duplifascialis* (Hampson), bud and shoot worm (gallery worm), *Elasmopalpus jasminophagus* (Hampson), leaf webber, *Nausinoe geometralis* Guenee, leaf roller, *Glyphodes unionalis* Guenee, Flower thrips, *Thrips orientalis* Bagnall and the blossom midge, *Contarinia maculipennis* Felt. Among mites, *Tetranychus lombardini* Baker & Pritchard and eriophyid mite, *Aceria jasmine* are prominent. Eriophyid mite damage is increasing due to prevailing hot weather conditions (Kamala and Kennedy, 2016).

In recent years, the bud worm, *H. duplifacialis* is known to pose a serious threat for jasmine cultivation. The caterpillar makes a hole on the flower bud and feeds on the inner floral structures during the initial stage and later makes a circular hole on the bud and comes out for attacking the adjacent buds in the same cymose. The larva even makes tunnels with silk and excreta within affected flower cluster/cymose thus affecting the opening of the flower buds. During severe infestation, the larva makes a web like structure. The infested flowers dry up and drop off (Kamala and Kennedy, 2016). The damage caused by bud worm ranges from 40 to 50 per cent, affecting the quality of flowers and attributed for 30 to 70 per cent yield loss (Gunasekaran, 1989). Though the incidence of bud borer, *H. duplifascialis* is persistent throughout the year, the peak incidence is during July, August and September (Lanfang *et al.,* 2007).

In Ramanagara district where estimated area under jasmine cultivation is more than 250 hectares, many small and marginal farmers growing *J. multiflorum* are finding difficulty in getting profit due to many reasons. Most of the gardens are 20-25 years old and poorly maintained which resulted in low flower productivity and poor quality flowers. In addition to this, budworm has become a potential threat for flower production in the recent past (Farmers Personal Communication, 2017).

Material and Methods

Distribution Pattern of the Jasmine Budworm and Infestation

The field studies on distribution pattern of bud worm infestation were conducted in the untreated jasmine plots at Chandurayanahalli, Magadi taluk, Ramanagara district at 12°97' N latitude, 77°19' E longitude. For the study, thirty jasmine plants infested with budworm were randomly selected and tagged. The selected plants in the garden were pruned during March, 2020 as a rejuvenation practice. The average height of the plants in the garden during the study in the month of September, 2020 was 2 meters. So the infested plant height was divided into four equal canopy intervals of 0-50 cm, 51-100 cm, 101-150 cm and 151-200 cm from ground level (Plate 1). Further at each canopy levels, two branches were selected randomly and tagged. From each branch, ten cymoses were selected and number of buds damaged was recorded separately. Later the number of buds damaged at each canopy interval was added-up to total number of buds damaged per plant. The study was carried out both in jasmine monocrop (Plate 2) and jasmine intercrop (Plate 3) in coconut plantation to know any impact of shade on distribution of the budworm infestation.

Plate 1 : Recording on bud worm infestation at different canopy height intervals on *Jasminum multiflorum*

Plate 2 : Field view of jasmine monocrop

Plate 3 : Field view of jasmine intercropped with coconut

Spatial Distribution

Spatial distribution of jasmine budworm was studied by calculating the variance-mean ratio by using descriptive statistics. Various indices of dispersion were used to analyse the *Hendecasis duplifascialis* distribution, without any prior assumptions of the type of distribution. The three basic units used for fitting the distribution were mean (x), variance (s^2) and the number of samples (n) on which the mean is based. The pattern of bud worm infestation distribution was studied by using the following statistical tools.

a) Variance-Mean Ratio (VMR) : The index of dispersion is a measure of dispersion for nominal variables and partially ordered nominal variables. It is usually defined as the ratio of the variance to the mean (VMR). The formula is as follows,

$$D = \sigma^2 / \mu$$

Where, σ^2 is the variance and μ is the mean.

Depending on the intensity of the infestation and frequency of distribution, mean (x) and variance (s^2) were determined for the observations on jasmine monocropping and intercropping, to work out the Variance Mean Ratio (Elliott, 1979). Based on the VMR, the type of distribution was ascertained.

If the VMR= Unity, it shows Poisson or Random distribution, < unity indicates regular or under dispersion or positive binomial distribution and > unity indicates Aggregate or Clumped or Negative binomial distribution.

b) Exponent 'k' : The value of 'k' of the negative binomial, which is a measure of the amount of clumping and is often, referred to as the dispersion parameter, was calculated with the following formula.

$$\mathbf{k} = \frac{\mathbf{x}}{\mathbf{s^2 - x}}$$

Where, x is the mean and s^2 is the variance. The value of the exponent 'k' above 1 indicates random distribution, fractional 'k' values (Southwood, 1978) indicate aggregate or clumped distribution and negative value indicates regular distribution or under dispersion, variance-mean ratio and the 'k' value were the parameters used to understand the aggregation or randomization or under dispersion pattern of jasmine bud worm infestation.

c) *David and Moore Index (I_{DM})* : The index of clumping of David and Moore (1954) was calculated with the following formula,

$$I_{DM} = \left\{\frac{s^2}{x}\right\} - 1$$

The value zero indicates, random distribution, positive value for the negative binomial and negative value for the positive binomial.

Correlation Matrix and Models

The number of the damaged buds at different canopy levels was subjected to correlation matrix analysis with total number of damaged buds in each plant. The damaged buds at different canopy levels showing significant relationship at p=0.05 were identified and subjected to further linear and non-linear analysis. Multiple regression analysis was carried out when more than one factor was involved.

Single Factor Models Using Scatter Plot and Trend Line : The models as follows were found relevant in the present investigation. This was calculated for a line represented by y = a + bx, where y = the predicted population, x = factor, a = the intercept (a = y- bx) and b = slope.

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2}$$

Where, y is the dependent array of means and x is the independent array of the factor identified.

Polynomial Model : Polynomial model is a form of regression analysis in which the relationship between the independent variable (*x*) and the dependent variable (*y*) is modelled as an n^{th} degree polynomial in *x*. Polynomial regression fits a nonlinear relationship between the value of *x* and the corresponding conditional mean of *y*, denoted E(*y*/*x*) and calculates the least squares fit through points by using the following equation.

$$y = b + c_1x^1 + c_2x^2 + c_3x^3 \ldots\ldots\ldots\ldots c_nr^n$$

Where, 'c' are co-efficients and 'n' is degree of polynomial, R = square (R^2) or coefficient of determination (CD)

The relevant models were computed and the appropriate trend lines for the models with maximum R^2 values and the figures were plotted.

Taylor Power Model : This is another non-linear regression model and calculates the least square fit through points by using the following equation.

$$y = cx^b,$$

where, c and b are constants

d) Logarithmic Model : This model calculates the least square fit through points by using the following equation.

$$y = c\ln x + b,$$

where, c and b are constants and 'ln' is the natural logarithm function.

e) Exponential Model : Linear regression can be used with relationships which are not inherently linear, but can be made to be linear after a transformation, such models are the exponential models and calculates the least square fit through points by using the following equation.

$$y = ce^{bx}$$

where, 'c' and 'b' constants and 'e' is the base of the natural logarithm

Results and Discussion

Spatial Distribution of *H. duplifascialis* Hampson Damage on *J. multiflorum*

The spatial distribution of *H. duplifascialis* damaged buds in jasmine ecosystem was computed for jasmine as monocrop (Set-I) and for jasmine intercrop with coconut (Set-II) with the help of various indices of dispersion as given in material and methods and the results are discussed below.

Spatial Distribution of *H. duplifascialis* Damage on *J. multiflorum* at Different Plant Heights Jasmine as Monocrop (Set-I)

The different indices of dispersion for damaged buds by bud worm, *H. duplifascialis* in jasmine are presented in Table 1. The values of the variance being greater than the mean ($s^2 > x$) for all the canopy levels indicated that the distribution of the bud worm damage was clumped or aggregated.

The variance to mean ratio (VMR) varied for different canopy levels. At 0-50 cm height interval *i.e.*, at ground level the VMR value was below unity indicating regular or under dispersion or positive binomial distribution. The variance to mean ratio (VMR) at remaining three canopy heights *viz.,* 51-100 cm, 101-150 cm and 151-200 cm were more than unity indicating aggregate or clumped or negative binomial distribution.

This variation in distribution was further confirmed by the fractional values of 'k' (Table 1). In all the canopy heights intervals, the dispersion parameter of 'k' was variable. At canopy levels of 0-50 cm *i.e.,* at the ground level, the 'k' value was negative indicating regular distribution or under dispersion. At 51-100 cm of the plant, the value of the exponent 'k' was above unity indicating random distribution. At canopy levels of 101-150 cm and 151-200 cm, fractional 'k' value indicated aggregate or clumped distribution of the pest incidence.

Table 1

Spatial distribution of *H.*

Height intervals of the plant (cm)	Mean number of damaged buds	V/M	K	I_{DM}
Monocrop				
0-50	3.47	0.93	-15.31	-0.07
51-100	7.62	1.21	4.70	0.21
101-150	14.60	2.11	0.90	1.11
151-200	14.37	2.01	0.99	1.01
Inter-cropped with coconut				
0-50	5.00	0.70	-3.30	-0.30
51-100	9.48	0.84	-6.21	-0.16
101-150	17.73	2.04	0.96	1.04
151-200	17.98	2.09	0.92	1.09

V/M – variance mean ratio, k- negative binomial, IDM- David and Moore index

Further these findings were supported by David and Moore index (I_{DM}) values, which were negative at the base indicating regular or under dispersion or positive binomial distribution. At other three canopy height intervals, I_{DM} values were positive, indicating negative binomial distribution or aggregated distribution of *H. duplifascialis* damage.

Jasmine as Intercrop with Coconut (Set-II)

The values of various indices of dispersion *viz.,* VMR, 'k' value and David and Moore index (I_{DM}) are presented in Table 1. The value of variance being lesser than mean ($s^2 < x$) at canopy height intervals 0-50 cm and 51-100 cm which indicated regular distribution and the values of the variance being greater than the mean ($s^2 > x$) for canopy height intervals 101-150 cm and 151-200 cm which indicated that the distribution of the bud worm damage was clumped or aggregated.

The variance to mean ratio (VMR) varied at different canopy levels. The VMR at the canopy heights 0-50 cm and 51-100 cm were less than unity indicating regular or under dispersion or positive binomial distribution. The VMR values were more than unity at 101-150 cm and 151-200 cm indicating aggregated or clumped or negative binomial distribution.

The values of 'k' at canopy level of 0-50 cm and 51-100 cm indicated the regular distribution or under dispersion, the fractional 'k' values at 101-150 cm and 151-200 cm indicated aggregated or clumped distribution of the pest incidence.

The David and Moore Index (I_{DM}) at canopy height intervals 0-50 cm and 51-100 cm were negative, indicating positive binomial or regular or under dispersion and the positive value at the height intervals of 101-150 cm and 151-200 cm indicated the negative binomial or aggregated or clumped distribution of *H. duplifascialis* damage.

Spatial distribution is the characteristic of an insect species or its infestation/ damaged symptoms and is vital in developing the sampling plan. In the present study in monocropping, analysis of the damaged buds in the plants showed that the variance to mean ratios (VMR) were > 1 at 101-150 cm and 151-200 cm canopy height intervals, thus revealing that *H. duplifascialis* infestation followed an aggregate distribution pattern at the top most region. Similarly even in jasmine as intercrop also at the canopy height intervals 101-150 cm and 151-200 cm, the distribution pattern was aggregated or clumped. These results were supported by the studies related to spatial distribution conducted by Falerio *et al.* (2002) who reported that the red palm weevil population followed the negative binomial distribution pattern in coconut plantations and were highly aggregated or clumped at particular height interval.

The aggregated pattern of distribution in bud worm infestation may be due to the availability of the maximum number of buds and also dense clusters present at 101-150 cm and 151-200 cm canopy height intervals. Even the ample sunlight and micro climate conditions around the plants may also be favourable for the aggregation of bud worm infestation at middle and top regions of the plants. This is the most possible explanation for more infestation by bud worm at 101-150 cm and 151-200 cm canopy height intervals of jasmine plants from the ground level. The explanation for present findings were also supported by Bright (1968) and Keshavareddy *et al.* (2008) who have reported that at a particular height interval, moisture on outer bark of the main trunk in grapes is one of the predominent factor which leads to adequate fungal growth and also change in micro climate around the plant for aggregated distribution of shot hole borer attack in grapes.

Further, at the ground level the number of cymoses and buds were relatively less when compared to the middle and top regions of the jasmine plant. Thus the distribution pattern of bud worm damage in a plant is very important for planning effective sampling strategies. Sampling plan in turn was very crucial for estimating pest densities or infestation intensity for scheduling pest management programmes as reported by Keshavareddy (2004).

Relationship between Number of Damaged Buds at Different Levels of the Canopy with the Total Number of Damaged Buds in a Plant Monocropping (Set-I)

The data on number of the damaged buds at different height intervals of a plant and total number of damaged buds were subjected to correlation matrix. The number of damaged buds at different height intervals showed significant positive correlation with total number of damaged buds in a plant. However, the damaged buds present at 101-150 cm and 151-200 cm height intervals showed higher 'r' values of 0.96 and 0.94, respectively (Table 2).

Jasmine as Intercrop with Coconut (Set-II)

The number of the damaged buds at different height intervals of a plant and total number of damaged buds were subjected to correlation. The number of damaged buds at different plant height intervals showed significant positive correlation with total number of damaged buds in a plant. However, the damaged buds present at 101-150 cm and 151-200 cm height intervals showed higher 'r' values of 0.96 and 0.93, respectively (Table 2).

The correlation coefficients were worked out to know if the number of damaged buds at different height intervals were related to the total number of damaged buds in a plant. In both cases jasmine as monocrop and as an intercrop in coconut, it was found that the density of damaged buds at all height intervals were significantly and positively correlated with total number of buds damaged in a plant (Table 2). However, 101-150 cm and 151-200 cm height intervals showed higher 'r' values. This implied that maximum number of buds damaged were present at 101-150 cm and 151-200 cm from the ground level on a plant and these damaged buds influence the total number in two sets of evaluation. The more damage to the buds at middle and top regions of the jasmine plant is due to clusters of flowers in terminal umbellate cymoses on side shoots.

Estimation Models

Monocropping (Set –I)

Estimation models were developed with the number of damaged buds at the height interval of 101-150 cm as the independent variable (x). When the total number of damaged buds were regressed against the number

TABLE 2

Correlation between number of damaged buds at different height intervals and total number of damaged buds in jasmine

Height intervals of the plant (cm)	Total number of damaged buds at different height intervals			
	0-50 cm	51-100 cm	101-150 cm	151-200 cm
Jasmine (monocrop)				
51-100 cm	0.55			
101-150 cm	0.37	0.64		
151-200cm	0.30	0.59	0.92	
Total	0.52	0.79	0.96	0.93
Jasmine (inter-cropped with coconut)				
51-100cm	0.57			
101-150cm	0.27	0.66		
151-200cm	0.27	0.61	0.93	
Total	0.47	0.80	0.96	0.94

of damaged buds at 101-150 cm height interval, exponential model ($y = 19.60e^{0.05x}$), linear model ($y = 2.29x + 10.50$), logarithmic model ($y = 32.25Ln(x) - 40.32$), polynomial model ($y = -0.025x^2 + 3.108x + 4.609$) and power model ($y = 5.769x^{0.76}$) could explain the variability in the former to the extent of 86.60, 91.18, 88.73, 91.67 and 90.13 per cent, respectively, due to the damaged buds at the height interval of 101-150 cm. However, the best fit was obtained by the polynomial model ($y = -0.025x^2 + 3.108x + 4.609$) which explains the variability of 91.67 per cent ($R^2 = 0.9167$) (Table 3).

Similarly, when the total number of damaged buds of a plant were regressed against the number of damaged buds at 151-200 cm height interval, exponential model ($y = 14.53e^{0.06x}$), linear model ($y = 2.48x - 1.27$), logarithmic model ($y = 42.32Ln(x) - 77.27$), polynomial model ($y = 0.002x^2 + 2.410x - 0.646$) and power model ($y = 2.275x^{1.02}$) could explain the variability in the former to the extent of 87.45, 86.77, 84.06, 86.77 and 89.03 per cent, respectively, due to the damaged buds at the height interval of 151-200cm. However, the best fit was obtained by the power model ($y = 2.275x^{1.02}$) with the variability of 89.03 per cent ($R^2 = 0.8903$) (Table 3).

The predicted total number of damaged buds in each jasmine plant were calculated by using polynomial model and linear model at 101-150 cm (Table 3) (Fig. 1 & 2). At 151-200 cm, power model and exponential model were used (Table 3) (Fig. 3 & 4). Later when the predicted total number of the damaged buds and the actual observed number of damaged buds of each plant were subjected to the t-test, it was observed to be non-significant at $p= 0.05$ (Table 4 & 5).

Jasmine as Intercrop with Coconut (Set-II)

When total number of damaged buds was regressed against the number of damaged buds at 101-150cm height interval, exponential model ($y = 24.24e^{0.04x}$), linear model ($y = 2.17x + 14.59$), logarithmic model ($y = 36.35Ln(x) - 49.38$), polynomial model ($y = -0.027x^2 + 3.163x + 6.184$) and power model ($y = 6.605x^{0.73}$) could explain the variability in the former to the extent of 87.54, 91.35, 90.56, 92.05 and 91.59 per cent, respectively. However, the best fit was obtained by the polynomial model ($y = -0.027x^2 + 3.163x + 6.185$) which explains the variability of 92.05 per cent ($R^2 = 0.9205$) (Table 6).

TABLE 3

Prediction models to predict total number of infested buds in a bush from infested buds present at different height intervals in jasmine monocrop

Models	Regression equation	R^2 Values	CD%
Height interval (101-150 cm)			
Exponential	$y = 19.60e^{0.05x}$	0.8660	86.60
Linear	$y = 2.29x + 10.50$	0.9118	91.18
Logarithemic	$y = 32.25Ln(x) - 40.32$	0.8873	88.73
Polynomial	$y = -0.025x^2 + 3.108x + 4.609$	0.9167	91.67
Power	$y = 5.769x^{0.76}$	0.9013	90.13
height interval (151-200 cm)			
Exponential	$y = 14.53e^{0.06x}$	0.8745	87.45
Linear	$y = 2.48x - 1.27$	0.8677	86.77
Logarithemic	$y = 42.32Ln(x) - 77.27$	0.8406	84.06
Polynomial	$y = 0.002x^2 + 2.410x - 0.646$	0.8677	86.77
Power	$y = 2.275x^{1.02}$	0.8903	89.03

CD = Co-efficient of determination

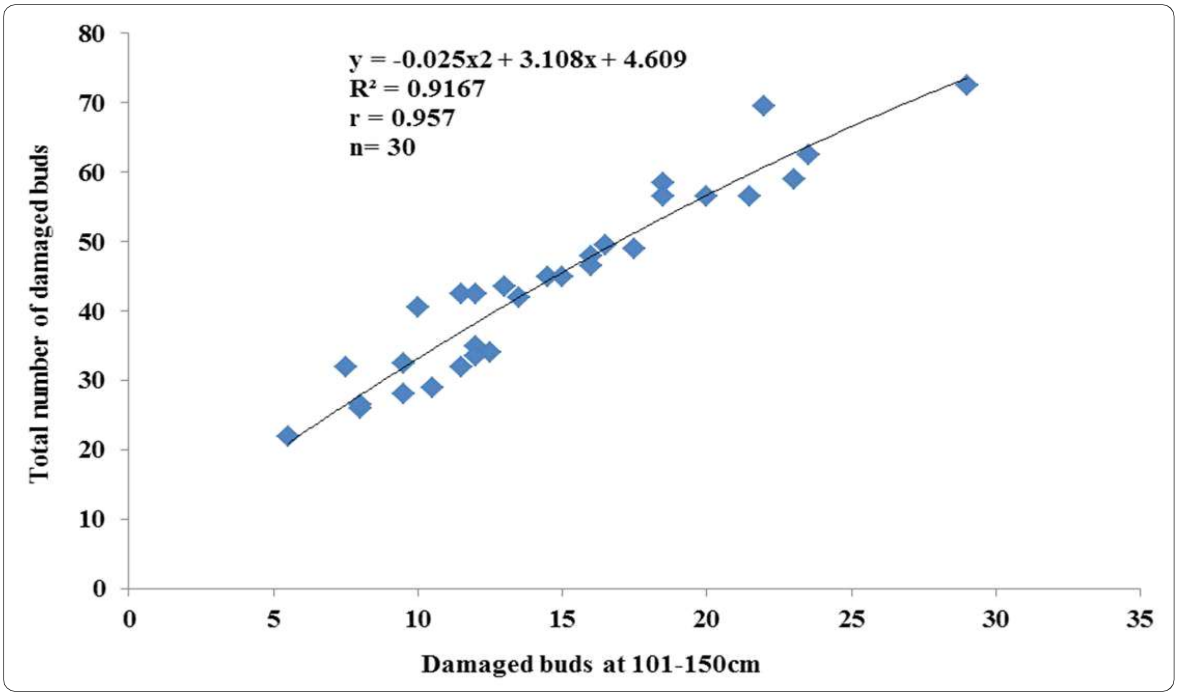

Fig. 1: Polynomial model at height interval of 101-150cm in jasmine mono-crop

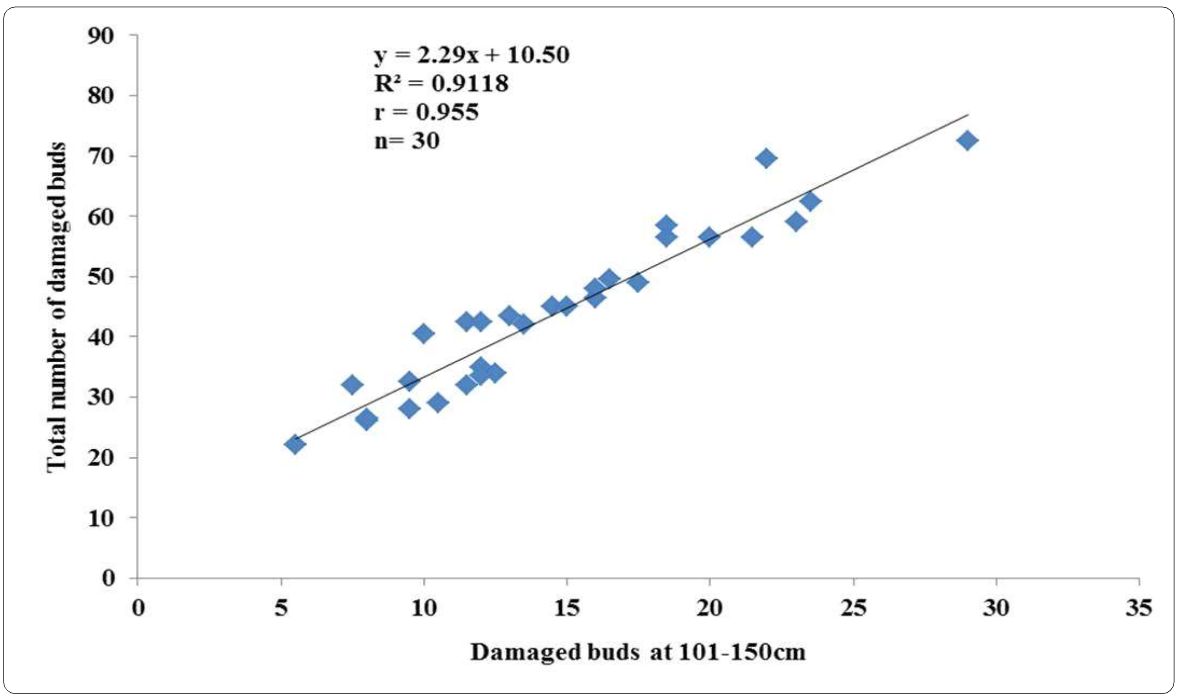

Fig. 2 : Linear model at height interval of 101-150cm in jasmine mono-crop

Similarly, the number of damaged buds at 151-200 cm height interval as independent variable (x) when subjected to regression with total number damaged buds of a plant as dependent variable, exponential model ($y = 17.95e^{0.05x}$), linear model ($y = 2.55x - 0.04$), logarithmic model ($y = 50.49Ln(x) - 98.71$), polynomial model ($y = -0.021x^2 + 3.446x - 8.982$) and power model ($y = 2.397x^{1.02}$) could explain the

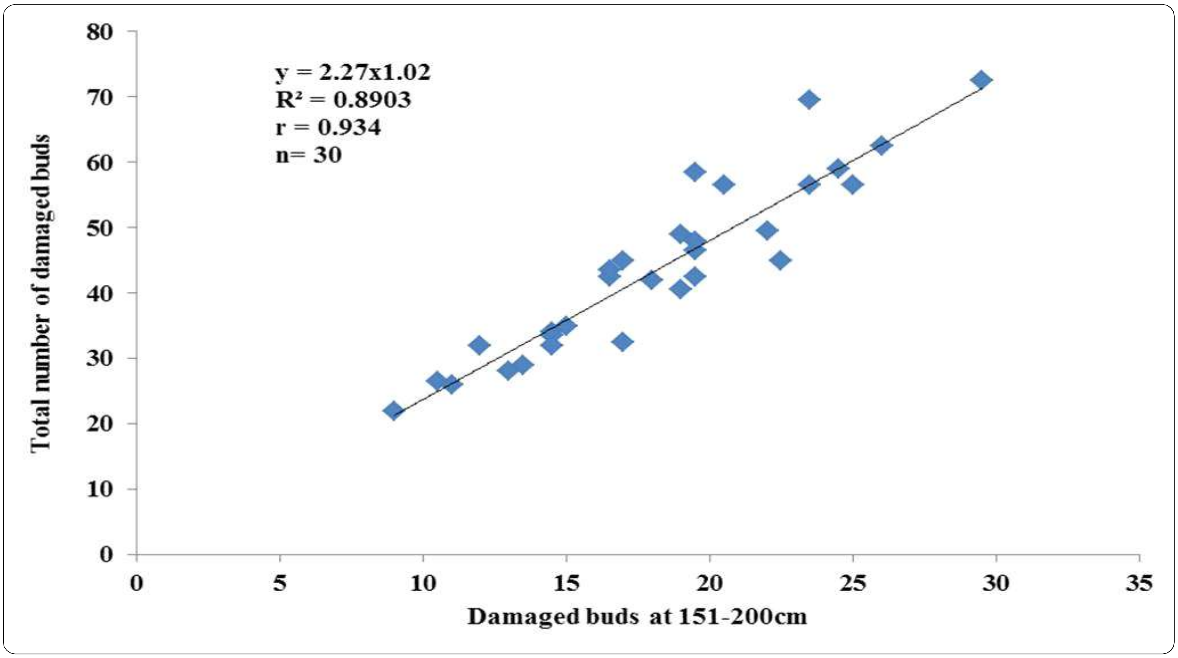

Fig. 3: Power model at height interval of 151-200cm in jasmine mono-crop

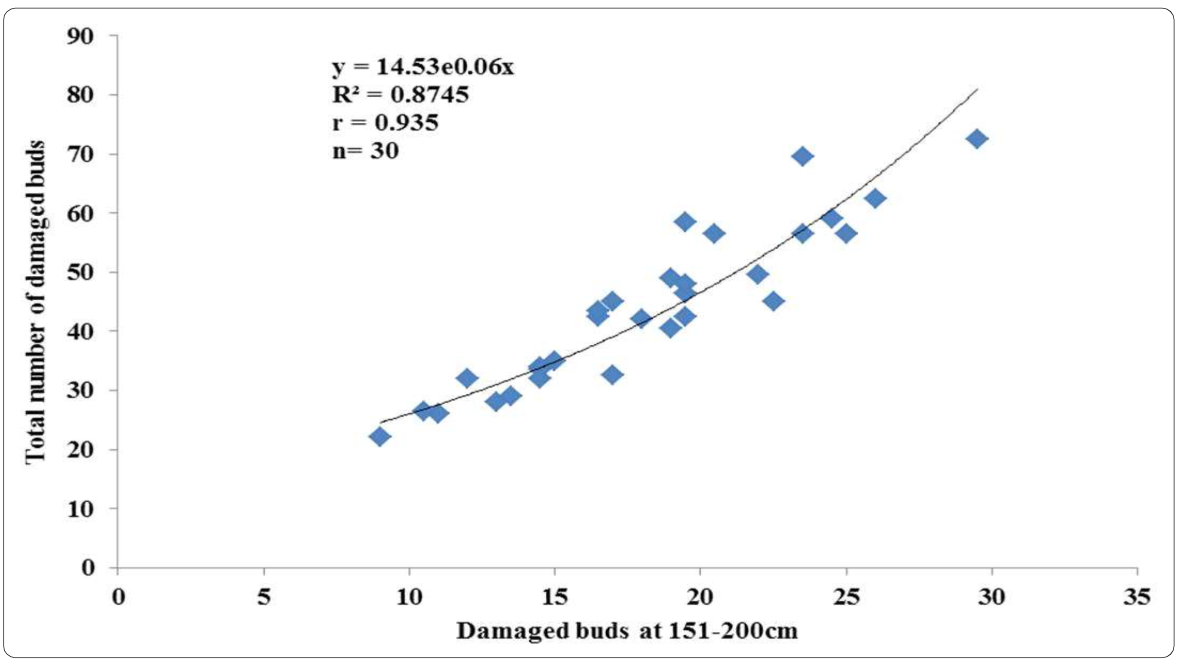

Fig. 4: Exponential model at height interval of 151-200cm in jasmine mono-crop

variability in the former to the extent of 87.52, 88.63, 87.83, 88.87 and 90.41 per cent, respectively. However, the best fit was obtained by the power model ($y = 2.397x^{1.02}$) with the variability of 90.41 per cent ($R^2 = 0.9041$) (Table 6).

The predicted total number of the damaged buds of the entire plant was calculated by using polynomial model and power model at 101-150 cm (Table 6) (Fig. 5 & 6). Even at 151-200 cm the same models were used (Table 6) (Fig. 7 & 8) by substituting 'x'

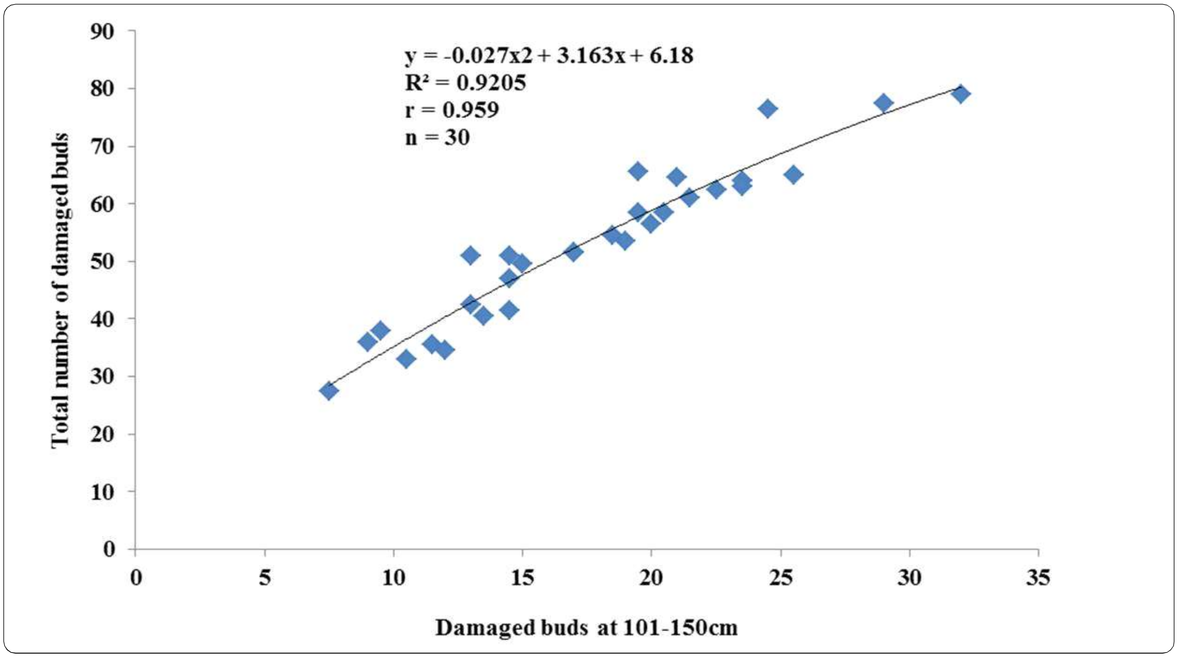

Fig. 5: Polynomial model at height interval of 101-150cm in jasmine inter-crop

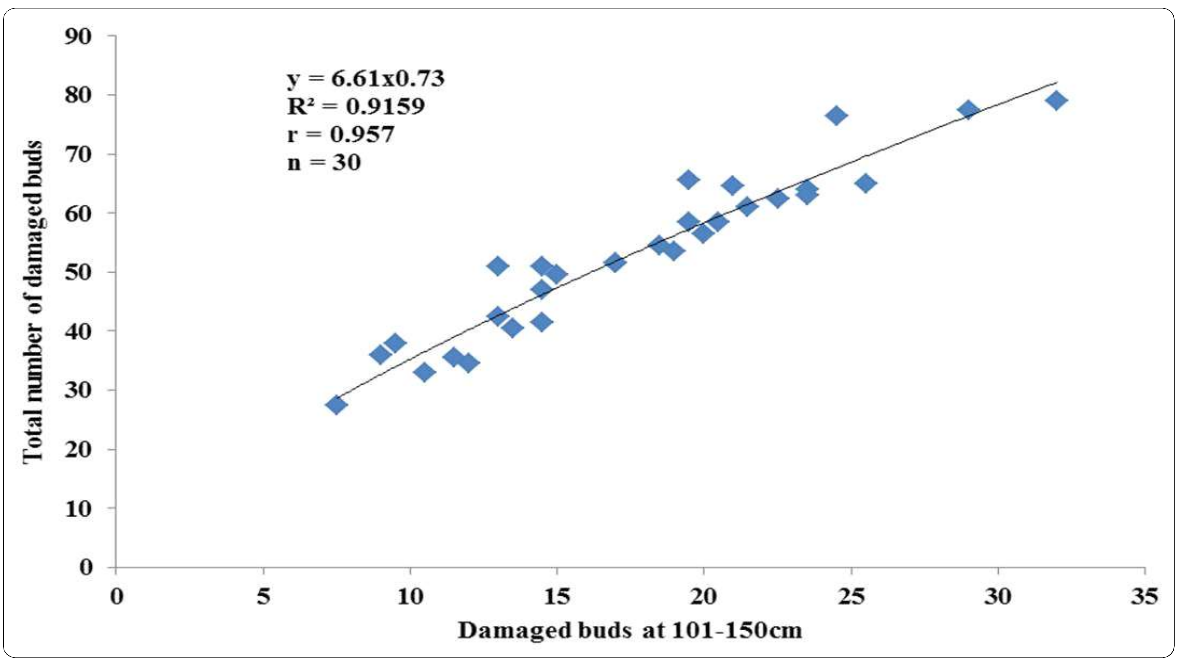

Fig. 6: Power model at height interval of 101-150cm in jasmine inter-crop

value as independent variable, respectively. Further the predicted total number of the damaged buds with the observed number of damaged buds were subjected to t-test, at p= 0.05 and was found to be non-significant (Table 7 & 8).

The estimation models are useful to determine the total number of damaged buds in a plant just by counting number of damaged buds at particular height interval. The polynomial models $y = -0.025x^2 + 3.108x + 4.609$ and $y = -0.027x^2 + 3.163x + 6.185$

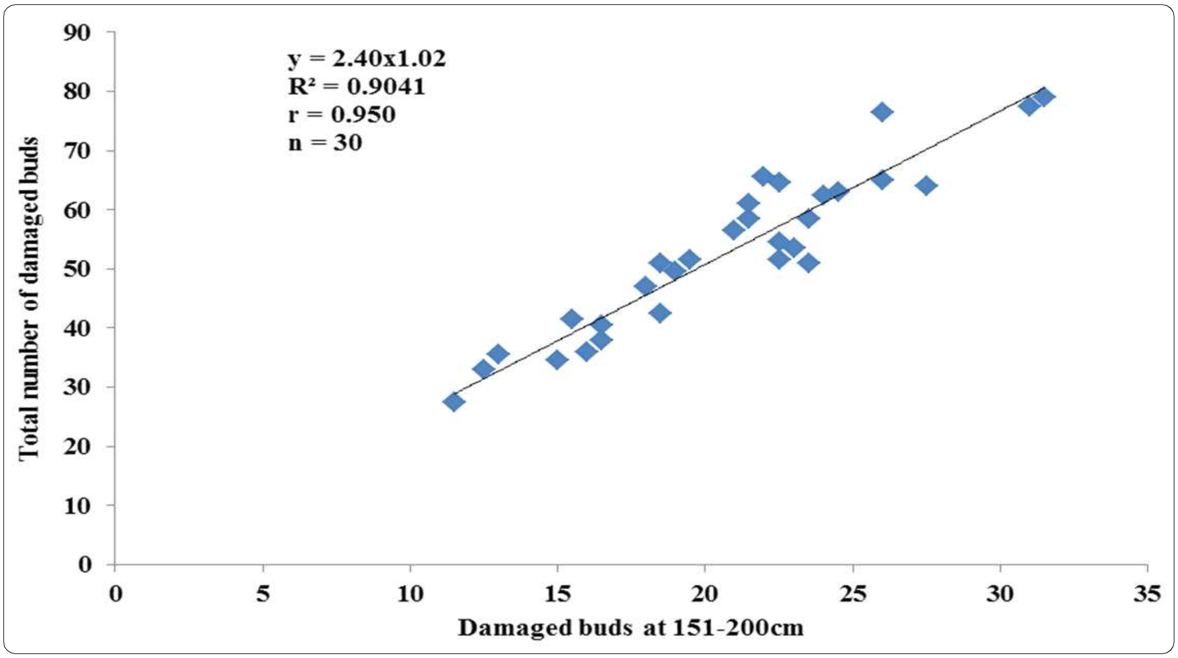

Fig. 7 : Power model at height interval of 151-200cm in jasmine inter-crop

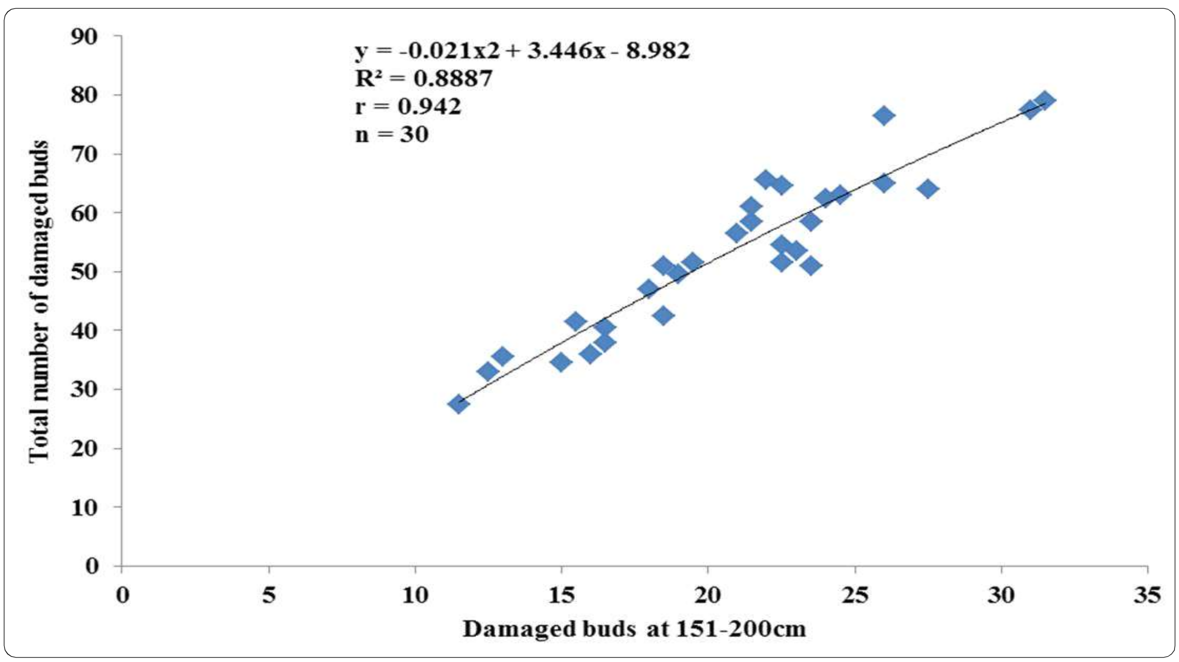

Fig. 8 : Polynomial model at height interval of 151-200cm in jasmine inter-crop

was found to be the best models at canopy height interval of 101-150 cm in both jasmine monocrop and also when intercropped with coconut, respectively. Similarly, at height interval 151-200 cm, in both the cases power models, $y = 2.275x^{1.02}$ and $y = 2.397x^{1.02}$ was found to be the best models and it was easy to estimate total number of buds damaged in a plant. These models are best suited to determine the severity of damage caused by the bud worm and helps in decision making for IPM implementation. The

Table 4

Prediction of total number of damaged buds in a bush from number of damaged buds at the height interval of 101-150 cm in mocropping

Number of damaged buds at 101-150 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using polynomial model)	Predicted (using linear model)
11.50	42.50	37.02	36.78
20.00	56.50	56.69	56.21
12.00	42.50	38.28	37.93
13.00	43.50	40.75	40.21
16.00	46.50	47.89	47.07
14.50	45.00	44.38	43.64
13.50	42.00	41.97	41.35
11.50	32.00	37.02	36.78
12.50	34.00	39.52	39.07
05.50	22.00	20.94	23.07
22.00	69.50	60.79	60.78
10.50	29.00	34.47	34.50
17.50	49.00	51.28	50.49
16.50	49.50	49.03	48.21
18.50	58.50	53.48	52.78
09.50	28.00	31.86	32.21
12.00	35.00	38.28	37.93
12.00	33.50	38.28	37.93
08.00	26.00	27.86	28.78
09.50	32.50	31.86	32.21
08.00	26.50	27.86	28.78
7.50	32.00	26.50	27.64
15.00	45.00	45.56	44.78
10.00	40.50	33.17	33.36
23.50	62.50	63.73	64.21
23.00	59.00	62.76	63.06
29.00	72.50	73.55	76.77
21.50	56.50	59.78	59.63
18.50	56.50	53.48	52.78
16.00	48.00	47.89	47.07
t- test (p= 0.05) n=30		NS	NS

NS = Non- significant

Table 5

Prediction of total number of damaged buds in a bush from number of damaged buds at the height interval of 151-200 cm in monocropping

Number of damaged buds at 151-200 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using power model)	Predicted (using exponential model)
19.50	42.50	46.81	45.21
25.00	56.50	60.28	62.27
16.50	42.50	39.49	37.97
16.50	43.50	39.49	37.97
19.50	46.50	46.81	45.21
17.00	45.00	40.71	39.09
18.00	42.00	43.15	41.43
12.00	32.00	28.55	29.22
14.50	34.00	34.62	33.80
9.00	22.00	21.30	24.54
23.50	69.50	56.60	57.06
13.50	29.00	32.19	31.89
19.00	49.00	45.59	43.92
22.00	49.50	52.93	52.29
19.50	58.50	46.81	45.21
13.00	28.00	30.98	30.97
15.00	35.00	35.84	34.80
14.50	33.50	34.62	33.80
11.00	26.00	26.13	27.57
17.00	32.50	40.71	39.09
10.50	26.50	24.92	26.78
14.50	32.00	34.62	33.80
22.50	45.00	54.15	53.84
19.00	40.50	45.59	43.92
26.00	62.50	62.74	66.00
24.50	59.00	59.05	60.48
29.50	72.50	71.35	80.91
23.50	56.50	56.60	57.06
20.50	56.50	49.25	47.92
19.50	48.00	46.81	45.21
t- test (p= 0.05) n=30		NS	NS

NS=Non- significant

TABLE 6

Prediction models to predict total number of infested buds in a bush/plant from infested buds present at height different height intervals in jasmine inter-cropped with coconut

Models	Regression equation	R^2 Values	CD%
Height interval (101-150 cm)			
Exponential	$y = 24.24e^{0.04x}$	0.8754	87.54
Linear	$y = 2.17x + 14.59$	0.9135	91.35
Logarithemic	$y = 36.35Ln(x) - 49.38$	0.9056	90.56
Polynomial	$y = -0.027x^2 + 3.163x + 6.185$	0.9205	92.05
Power	$y = 6.605x^{0.73}$	0.9159	91.59
Height interval (151-200 cm)			
Exponential	$y = 17.95e^{0.05x}$	0.8752	87.52
Linear	$y = 2.55x - 0.04$	0.8863	88.63
Logarithemic	$y = 50.487Ln(x) - 98.71$	0.8783	87.83
Polynomial	$y = -0.021x^2 + 3.446x - 8.982$	0.8887	88.87
Power	$y = 2.397x^{1.02}$	0.9041	90.41

CD = Co-efficient of determination

predicted models developed have two important functions, one is to determine the extent of bud worm infestation for IPM based decisions.

TABLE 7

Prediction of total number of damaged buds in a bush/plant from number of damaged buds at the height interval of 101-150 cm in jasmine intercroping with coconut

Number of damaged buds at 101-150 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using polynomial model)	Predicted (using power model)
13.00	51.00	42.82	42.66
23.50	64.00	65.88	65.63
15.00	49.50	47.67	47.34
14.50	51.00	46.48	46.19
19.50	58.50	57.78	57.30
17.00	51.50	52.30	51.86
20.00	56.50	58.84	58.36
14.50	41.50	46.48	46.19

Continued....

TABLE 7 Continued....

Number of damaged buds at 101-150 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using polynomial model)	Predicted (using power model)
9.00	36.00	32.50	32.65
7.50	27.50	28.42	28.60
24.50	76.50	67.77	67.64
12.00	34.50	40.32	40.25
21.50	61.00	61.94	61.51
20.50	58.50	59.89	59.42
19.50	65.50	57.78	57.30
13.50	40.50	44.05	43.85
14.50	47.00	46.48	46.19
17.00	51.50	52.30	51.86
11.50	35.50	39.05	39.02
13.00	42.50	42.82	42.66
10.50	33.00	36.47	36.53
9.50	38.00	33.84	33.96
19.00	53.50	56.71	56.23
18.50	54.50	55.63	55.15
29.00	77.50	75.62	76.47

Continued....

TABLE 7 Continued....

Number of damaged buds at 101-150 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using polynomial model)	Predicted (using power model)
25.50	65.00	69.61	69.64
32.00	79.00	80.26	82.15
23.50	63.00	65.88	65.63
21.00	64.50	60.92	60.47
22.50	62.50	63.93	63.58
t- test (p= 0.05) n=30		NS	NS

NS- Non- significant

TABLE 8

Prediction of toatal number of damaged buds in a bush/plant from number of damaged buds at the height interval of 151-200 cm in jasmine intercroping

Number of damaged buds at 151-200 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using power model)	Predicted (using polynomial model)
23.50	51.00	59.82	60.29
27.50	64.00	70.21	69.74
19.00	49.50	48.17	48.83
18.50	51.00	46.88	47.51
21.50	58.50	54.64	55.30
19.50	51.50	49.46	50.15
21.00	56.50	53.34	54.03
15.50	41.50	39.14	39.33
16.00	36.00	40.43	40.72
11.50	27.50	28.88	27.84
26.00	76.50	66.31	66.28
15.00	34.50	37.86	37.93
21.50	61.00	54.64	55.30
23.50	58.50	59.82	60.29
22.00	65.50	55.93	56.56
16.50	40.50	41.72	42.10

Continued....

TABLE 8 Continued....

Number of damaged buds at 151-200 cm	Total number of damaged buds in a bush (plant)		
	Observed	Predicted (using power model)	Predicted (using polynomial model)
18.00	47.00	45.59	46.17
22.50	51.50	57.23	57.82
13.00	35.50	32.72	32.23
18.50	42.50	46.88	47.51
12.50	33.00	31.44	30.78
16.50	38.00	41.72	42.10
23.00	53.50	58.52	59.06
22.50	54.50	57.23	57.82
31.00	77.50	79.33	77.46
26.00	65.00	66.31	66.28
31.50	79.00	80.64	78.52
24.50	63.00	62.42	62.71
22.50	64.50	57.23	57.82
24.00	62.50	61.12	61.51
t- test (p= 0.05) n=30		NS	NS

NS- Non- significant

and the other is to monitor levels of bud worm population, as the extent of infestation is an indirect estimate of the insect population (Southwood, 1978).

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