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Population Dynamics and Forewarning Models for Prediction of Population of *Maruca vitrata* under Different Sowing Window and Pigeonpea Varieties

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ABSTRACT

The correlation was carried out between weather parameter and population of *Maruca vitrata* on different pigeonpea varieties at different sowing windows and forewarning models for prediction of population of *H. armigera*, during 2017-18 and 2018-19. An experiment was laid out in split plot design with three replications. The treatment comprised of four varieties viz.,V_1: Vipula, V_2: Rajeshwari (Phule T 0012), V_3: BDN 711 and V_4: ICPH 2740 *(Mannem Konda Kandi)* as main plot and four sowing windows viz., D_1: 24th MW (11th to 17th June), D_2: 26th MW (25th June to 01st July), D_3: 28th MW (9th to 15th July) and D_4: 30th MW (23rd to 29th July) as sub plot treatments.The population of *Maruca vitrata* larvae was increased gradually from 37th MW to 47th MW. The highest populations of larvae were 23.68 and 20.29 per five plants during 2017-18 and 2018-19, respectively, observed in var BDN 711. The overall correlation of weather parameters with seasonal incidence of *M. vitrata* found to have positively correlation with maximum temperature, morning relative humidity and bright sunshine whereas, minimum temperature, evening relative humidity and rainfall showed negative correlation. During first sowing window 24th MW (D_1) with var BDN 711 (V_3) the population of M. vitrata larvae per five plants for one week prior (W-1) was significantly positively correlated with maximum temperature (0.088 and 0.578*) and positively bright sunshine hrs (0.559* and 0.465). Prediction of *M. vitrata* populations one week prior (W-1) in different sowing window based on regression equations (R^2) 51.7 to 72.7 % validation for var Vipula, (R^2) 75.9 to 82.6 % validation for var Rajeshwari, (R_2) 63.7 to 79.0 % validation for var BDN 711 and (R^2) 52.0 to 88.5 % validation for var ICPH 2740. The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var BDN 711 and D1 sowing window (24th MW). The forewarning model found as number of *M. vitrata* larvae (Y) = 38.748+ 1.856 (T_{max}) – 0.252 (T_{min}) – 0.499 (RH I) – 0.577 (RH II) – 0.000 (Rain fall) – 1.934 (BSS). An increase of one unit of maximum temperature increased the population of *M. vitrata* by 1.856 units to an extent of 63.7 % (R^2=0.637).

Keywords Correlation, Forewarning models, Sowing windows, Varieties, *M. vitrata.*

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INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) is one of the major pulse crops of the tropics and subtropics. It is the second most important pulse crop of India, after chickpea (Nene *et al.* 1990). Pigeonpea is grown on an area of 4.43 m ha and production of 4.25 m tonnes the productivity is 960 kg $ha^{-}1$ in India (Anonymous 2019). Pigeonpea is grown throughout the country, except the hilly regions where winter temperature is very low. In India, Maharashtra, Andhra Pradesh and Gujarat account for a major pigeonpea growing states.

The production and productivity of this crop has remained stagnant over the past three decades due to its vulnerability to *biotic* and *abiotic* stresses. A large number of insect pests (more than 300 species) attack pigeonpea (Prasad and Singh 2004). Insects that attack the reproductive structures of plant cause the maximum yield losses (Rangaiah and Sehgal 1984). The most important pests those attack at flowering and podding stage of the crop are pigeonpea pod borer, *Helicoverpa armigera* (Hubner), spotted pod borer, *Maruca vitrata* (Fabricius), blue butterflies, *Lampides boeticus* L. and *Catochrysops strabo* (Fabricius), plume moth, *Exelastis atomosa* (Walsingham) and pod fly, *Melanagromyza obtusa* Malloch (Reed *et al*. 1989). Pod borers caused 60 to 90 % loss in the grain yield under favorable conditions, damage of seed by pod fly ranged from 14.3 to 46.6 % (Lal *et al.*1992) and loss of yield was recorded 60 to 80% due to the pod fly (Durairaj 2006).

Maruca vitrata, the legume pod borer, becomes more serious with an increase in precipitation and unseasonal rains. Drought stressed crops suffer greater damage because of greater vulnerability of stressed plants to insect damage (Sharma 2012). There is a need for a better understanding of the effect of climate change on pest incidence, expression of resistance and extent of losses due to pod borers in pigeonpea. The information on influences of *abiotic* factors on population dynamics is very scanty and the effect of variable weather and morphophysiological traits on the incidence of pod borer complex in pigeonpea will provide a base in the sound eco-based management program.

The sowing window is one of the crop habitat desertification that is to be looked into, to minimize the incidence of insect pests on pigeonpea crop so that its yield can be enhanced. The sowing window takes the advantage of the absence of the pest or avoids susceptible stage of the crop. It prevents carryover of pests from early sown crop to late sown crop and prevents buildup of damaging populations. The pest forewarning model was able to predict the percent population of pod borer for different pigeonpea varieties and sowing windows with good r^2 values.

Keeping these facts in view, the correlation between weather parameter and population of spotted pod borer (*M. vitrata*) larvae per five plants on different pigeonpea varieties at different sowing windows and development of forewarning models for prediction of population spotted pod borer (*M. vitrata*) larvae per five plants was studied during, 2017-18 and 2018-19.

MATERIALS AND METHODS

An experiment was laid out in split plot design with three replications and sixteen treatment combinations formed considering different varieties and sowing windows. The gross and net plot size was 4.0 × 4.5 m^2 and 3.6 × 4.0 m^2, respectively for two consecutive years at Department of Agricultural Meteorology farm, College of Agriculture, Pune during 2017-18 and 2018-19. The geographical location of the site (Pune) was 18° 32'N, latitude; 73°51E, longitude and 559 m above mean sea level (MSL). The soil is medium black having depth of about 1m. Pune is situated in the sub-tropical region (Plain Zone). The average annual rainfall of Pune is 675 mm, which is distributed from second fortnight of June to second fortnight of October. Out of total rainfall, about 75 % is received from June to September during south-west monsoon, while remaining is received from north-east monsoon (October and November). The maximum temperature during the month of April and May is ranged between 34^0C to 40^0C. But on the onset of monsoon, it drops down to 27^0C. In the month of July and August, it is ranged from 26 to 30 ^{0}C. The minimum temperature varied from 6 to 10 ^{0}C in winter season from November to middle of February. Humidity of monsoon period i.e., from June to September is quite high during morning (about 85 to 93 %). The evening humidity is generally ranged between 43 to 83 %. Urea and DAP were used as source of N and P and applied as per recommended dose i.e., 25 kg N and 50 kg. Seeds were treated with Thiram@ 4 g per kg of seed followed by *Rhizobium* and PSB@ 10 g per kg of seed.

Number of spotted pod borer larvae

The observation on the incidence of spotted pod borer larvae was recorded at weekly interval from five randomly selected and tagged plants from net plot. The effect of weather parameters viz., maximum and minimum temperatures (^{0}C), relative humidity (%) (morning and evening), bright sunshine hours, rainfall (mm) and rainy days, wind speed, evaporation rate on spotted pod borers were recorded from meteorological weeks 24th to 2nd during 2017-18 and 2018-19. The correlation studies were carried out between pest population, various above weather parameters of different sowing windows and varieties during 2017-18 and 2018-19. The multiple regression analysis was also worked out between spotted pod borer pest population and weather parameters.

The influence of weather parameters on pest population was estimated by using prediction equation as, Y = a + b1x1+b2x2+b3x3+.......+bnxn.

Where, Y= Pest population, 'a' as constant and 'b' as regression coefficients of independent variable 'x'. and also to study the influence of weather parameters on crop growth yield and yield attributes, initially simple correlations (Snedecor and Cochron 1968) were carried out. The forewarning models for different sowing windows and varieties of pigeonpea were worked out by statistical analysis using SPSS 8.0 software with multiple linear regression method. The correlation coefficient values were further used for results and discussion.

RESULTS AND DISCUSSION

During the course of study the incidence of *M. vitrata* was recorded on different pigeonpea varieties were sown at different sowing windows. The incidence of *M. vitrata* was recorded on all varieties during the year 2017-18 and 2018-19 and presented in Tables 1 - 4 and graphically depicted, in Figs. 1 - 4, across all sowing windows.

The larvae web the leaves and inflorescence and feed inside on flowers, flower buds and pods. The flower bud stage is preferred most for oviposition and it is at this stage that the young larvae cause substantial damage and reduce the crop potential for flowering and fruit setting. The young larvae bore into

Table 1. Mean number of spotted pod borer, *M. vitrata* on var Vipula as influenced by different sowing windows.

	Number of spotted pod borer larvae per five plants							
	2017-18				2018-19			
SWM	D_1(24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)	D_1 (24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)
37	0.38	0.66	0	0	0.36	0.16	0	0
38	0.81	0.95	0.61	0	0.86	0.94	0.64	0
39	1.34	1.67	1.55	0.76	1.64	1.62	1.87	0.53
40	3.64	3.35	2.08	1.84	2.94	3.86	3.64	2.67
41	5.67	5.84	4.67	4.67	5.67	4.37	4.32	3.08
42	8.69	8.64	7.84	6.51	7.66	7.39	6.86	5.39
43	12.67	11.37	11.98	8.57	9.31	12.68	9.37	7.16
44	13.58	16.84	14.37	10.3	13.64	15.05	13.64	9.06
45	16.84	19.31	17.85	13.66	15.37	17.31	14.66	11.85
46	13.64	21.58	19.67	16.23	12.85	18.34	16.04	12.73
47	11.38	16.38	20.54	18.31	10.61	15.34	16.82	14.88
48	8.54	13.64	16.97	15.08	7.35	11.08	13.68	11.06
49	4.38	7.53	12.66	10.65	4.26	7.54	9.54	8.67
50	1.62	4.61	7.19	6.27	1.3	3.94	6.51	7.81
51	0	2.1	4.36	3.53	0	1.06	3.67	4.08
52	-	0	1.35	0.28	-	0	0.89	1.33
Mean	6.88	8.40	8.98	7.29	6.25	7.54	7.63	6.27

Table 2. Mean number of spotted pod borer, *M. vitrata* on var Rajeshwari as influenced by different sowing windows.

	2017-18			Number of spotted pod borer larvae per five plants			2018-19	
SWM	D_1(24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)	D_1 (24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)
37	0.61	0.24	0.00	0.00	0.83	0.52	0.00	0.00
38	1.85	1.38	0.84	0.00	1.37	0.91	0.57	0.00
39	3.64	2.33	1.35	0.67	3.06	2.34	1.20	0.57
40	5.84	4.84	2.84	1.67	5.47	3.81	2.08	1.64
41	8.67	7.30	4.07	3.54	6.12	6.57	3.57	3.88
42	9.55	10.64	5.34	5.86	8.65	9.55	5.89	5.49
43	13.63	12.45	8.79	8.37	10.86	11.34	8.43	6.37
44	15.96	15.64	11.34	10.39	13.43	12.39	11.82	8.09
45	18.04	17.81	14.57	12.54	14.67	16.37	13.26	10.54
46	16.73	17.84	15.74	15.67	11.38	17.64	15.47	12.36
47	11.67	12.56	18.98	16.31	7.46	14.37	16.82	13.82
48	7.35	9.67	15.66	12.67	4.57	10.59	14.25	10.77
49	3.94	5.67	11.24	8.31	2.16	6.84	10.76	6.24
50	1.03	2.34	7.94	5.69	0.73	2.35	6.85	3.59
51	0.00	0.36	4.69	2.04	0.00	0.51	3.67	1.57
52	-	0.00	2.03	0.38	-	0.00	1.34	0.31
Mean	7.90	7.57	7.84	6.51	6.05	7.26	7.25	5.33

the flower buds and cause flower shedding by destroying the young flower parts enclosed in the sepals. The larval movement is facilitated by the silken threads, which are used as bridges between flowers. After initial dispersal, larval development is completed on several flowers /pods. The larvae move from one flower to another as they are consumed and a larva may consume 4 -6 flowers before larval development is completed. The successful establishment of this pest at the flower bud stage is significant in relation to subsequent damage, reduction in grain yield and efficiency of control.

Population dynamics of *M. vitrata* larvae per five plants on different pigeonpea varieties under sowing window (D_1) 24th MW

During the year 2017-18, first sowing window 24th

Table 3. Mean number of spotted pod borer, *M. vitrata* on var BDN 711 as influenced by different sowing windows.

	2017-18			Number of spotted pod borer larvae per five plants			2018-19	
SWM	D_1(24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)	D_1 (24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)
37	0.27	0.64	0.00	0.00	0.26	0.69	0.00	0.00
38	0.35	1.82	0.56	0.00	0.84	1.27	0.34	0.00
39	1.59	3.86	2.54	0.81	1.67	2.34	0.98	0.54
40	2.61	4.37	3.67	1.39	3.81	5.27	1.56	1.09
41	4.66	6.57	6.84	3.58	5.07	7.54	3.73	3.67
42	9.67	9.53	8.22	5.64	8.59	9.38	5.29	5.46
43	13.53	12.84	11.68	8.84	11.37	11.37	8.46	7.55
44	17.66	16.99	14.51	11.65	16.33	14.83	12.87	10.28
45	20.84	20.25	17.62	14.36	17.68	18.41	14.37	12.54
46	17.21	23.68	20.57	17.02	13.84	20.29	17.85	13.67
47	13.53	18.37	21.63	19.71	10.26	16.57	19.37	16.23
48	9.56	13.67	17.34	14.28	6.84	12.36	15.67	16.81
49	5.02	9.53	12.60	10.04	3.57	9.38	12.54	12.68
50	2.14	4.06	8.94	7.62	0.26	4.69	9.38	7.37
51	0.00	1.36	3.67	4.31	0.00	2.05	4.57	4.31
52	-	-	0.89	2.03	-	-	1.69	1.39
Mean	7.91	9.84	9.46	7.58	6.69	9.10	8.04	7.10

Table 4. Mean number of spotted pod borer, *M. vitrata* on var ICPH 2740 variety as influenced by different sowing windows.

	2017-18		Number of spotted pod borer larvae per five plants			2018-19		
SWM	D_1(24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)	D_1 (24th MW)	D_2 (26th MW)	D_3 (28th MW)	D_4 (30th MW)
37	0.54	0.37	0.52	0.00	0.84	1.36	0.57	0.00
38	0.95	0.73	1.37	0.84	2.34	2.68	1.26	0.57
39	1.29	1.56	2.96	1.37	5.19	3.08	3.57	1.25
40	4.87	3.54	3.74	2.69	7.46	5.43	4.68	3.58
41	8.94	7.06	5.76	4.85	10.85	8.37	5.16	4.21
42	9.21	10.55	7.61	6.49	12.66	13.64	5.94	6.53
43	12.37	13.56	9.22	9.58	13.73	15.97	9.57	9.38
44	16.31	17.38	13.61	13.66	15.94	17.82	12.67	10.21
45	17.68	19.64	15.34	14.38	13.62	18.64	15.61	11.32
46	14.35	20.96	16.08	16.08	10.43	15.20	17.34	12.95
47	11.66	17.55	18.00	16.22	7.64	11.06	14.37	13.55
48	8.27	13.67	14.64	14.57	5.31	8.57	11.09	10.49
49	5.94	10.82	11.82	10.34	3.26	5.61	7.54	7.43
50	3.51	6.59	7.69	6.53	1.24	3.08	3.61	5.46
51	1.37	3.24	4.22	3.95	0.53	2.16	1.24	2.85
52	0.00	1.23	3.13	1.57	0.00	0.53	0.68	1.33
37	7.33	9.28	8.48	7.70	6.94	8.33	7.18	6.32

MW (D_1) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence of 6.88, 7.90, 7.91 and 7.33 larvae per five plants and which were at peak with 16.84, 18.04, 20.84 and 17.68 larvae per five plants. During the year 2018-19, the first sowing window 24th MW (D_1) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence was 6.25, 6.05, 6.69 and 6.94 larvae per five plants and which were at peak with 15.37, 14.67, 17.68 and 15.94 larvae per five plants. The peak population of larvae was noticed at 45th MW with sowing window 24th MW, during both the year 2017-18 and 2018-19. These results are in conformity with the results of Reddy *et al*. (2001), Chetan *et al*. (2013), Rathore *et al*. (2017).

Population dynamics of *M. vitrata* larvae per five

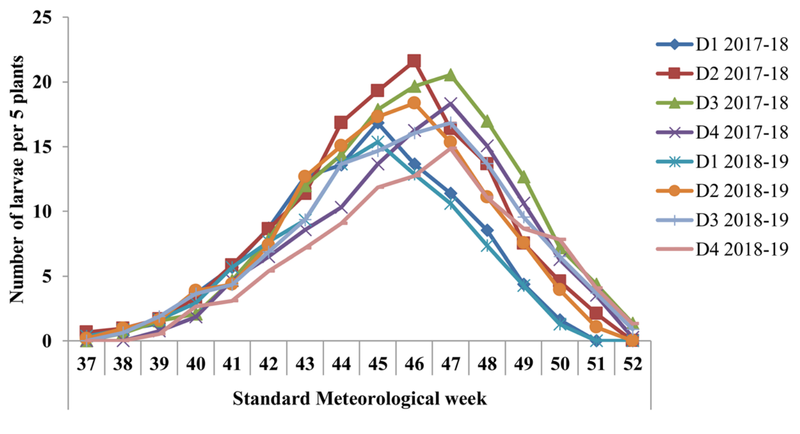

Fig. 1. Mean number spotted of pod borer (*Maruca vitrata*) on var Vipula (V_1) as influenced by different sowing windows.

Fig. 1. Mean number spotted of pod borer (*Maruca vitrata*) on var Vipula (V_1) as influenced by different sowing windows.

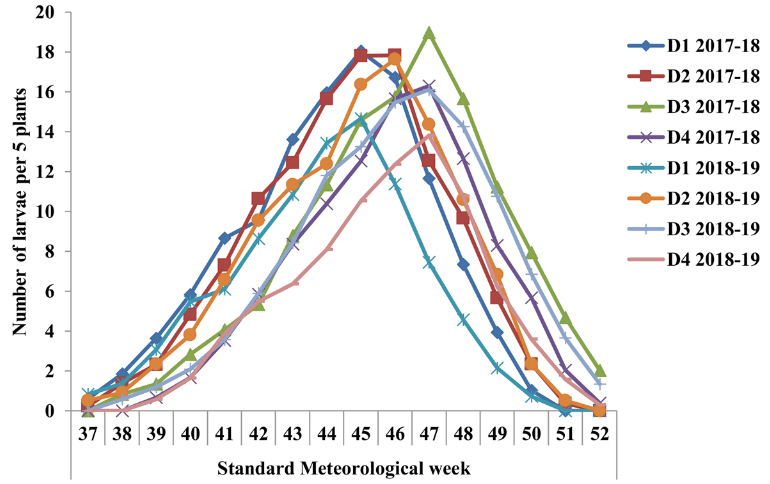

Fig. 2. Mean number of spotted pod borer (*Maruca vitrata*) on var Rajeshwari (V_2) variety as influenced by different sowing windows.

Fig. 2. Mean number of spotted pod borer (*Maruca vitrata*) on var Rajeshwari (V_2) variety as influenced by different sowing windows.

plants on different pigeonpea varieties under sowing window (D_2) 26th MW

During the year 2017-18, second sowing window 26th MW (D_2) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence of 8.40, 7.57, 9.84 and 9.28 larvae per five plants and which were at peak with 21.58, 17.84, 20.29 and 20.96 larvae per five plants. During the year 2018-19, the second sowing window 26th MW (D_2) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence was 7.54, 7.26, 9.10 and 8.33 larvae per five plants and which were at peak with 18.34, 17.64, 20.29 and 18.64 larvae per five plants. The peak population of larvae was noticed at 46th MW

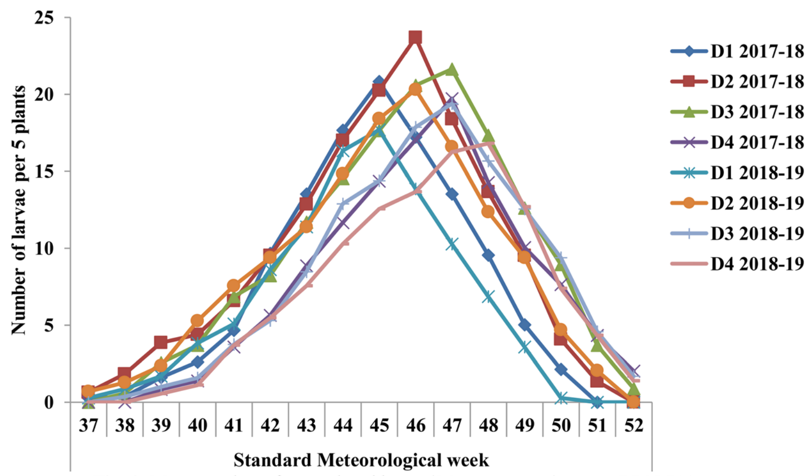

Fig. 3. Mean number of spotted pod borer (*Maruca vitrata*) on var BDN 711 (V_3) as influenced by different sowing windows.

Fig. 3. Mean number of spotted pod borer *(Maruca vitrata)* on var BDN 711 (V_3) as influenced by different sowing windows.

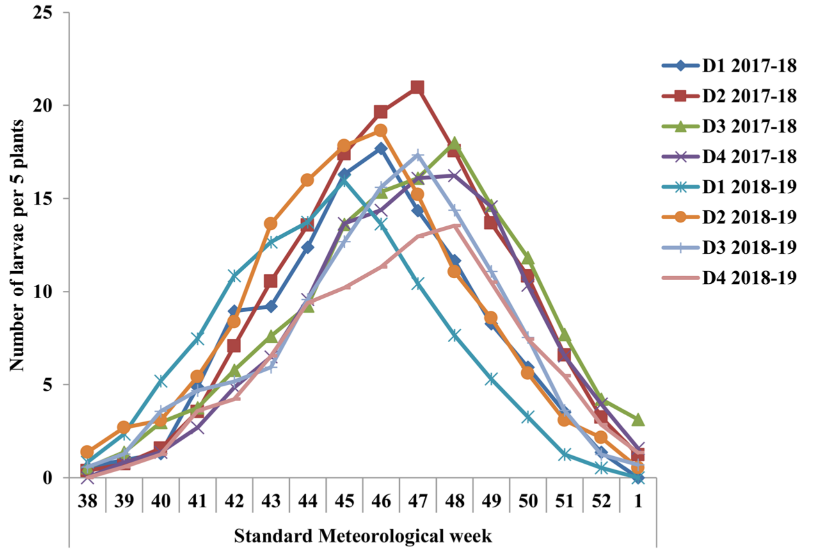

Fig. 4. Mean number of spotted pod borer (*Maruca vitrata*) on var ICPH 2740 (V_4) as influenced by different sowing windows.

Fig. 4. Mean number of spotted pod borer (*Maruca vitrata*) on var ICPH 2740 (V_4) as influenced by different sowing windows

with sowing window 26th MW, during both the year 2017-18 and 2018-19. These results are in conformity with the results of Reddy *et al*. (2001), Chetan *et al.* (2013), Rathore *et al.* (2017).

Population dynamics of *M. vitrata* larvae per five plants on different pigeonpea varieties under sowing window (D_3) 28th MW

During the year 2017-18, third sowing window 28th MW (D_3) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence of 8.98, 7.84, 9.46 and 8.48 larvae per five plants and which were at peak with 20.54, 18.98, 21.63 and 18.00 larvae per five plants. During the year 2018-19, the third sowing window 28th MW (D_3) with the varVipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence was 7.63, 7.25, 8.04 and 7.18 larvae per five plants and which were at peak with 16.82, 16.12, 19.37 and 17.34 larvae per five plants, resulted the peak population of larvae was noticed at 47th MW with sowing window 28th MW, during both the year 2017-18 and 2018-19, respectively. These results are in conformity with the results of Reddy *et al*. (2001), Chetan *et al*. (2013), Rathore *et al.* (2017).

Population dynamics of *M. vitrata* larvae per five plants on different pigeonpea varieties under sowing window (D_4) 30th MW

During the year 2017-18, second sowing window 30th MW (D_4) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence was 7.29, 6.51, 7.58 and 7.70 larvae per five plants and which were at peak with 18.31, 16.31, 19.71 and 16.22 larvae per five plants. During the year 2018-19, the first sowing window 30th MW (D_4) with the var Vipula (V_1), Rajeshwari (V_2) and BDN 711 (V_3) and ICPH 2740 (V_4) recorded the mean incidence was 6.27, 5.33, 7.10 and 6.32 larvae per five plants and which were at peak with 14.88, 13.82, 16.81 and 13.55 larvae per five plants, resulting the peak population of larvae was noticed at 47th MW with sowing window 30th MW, during both the year 2017-18 and 2018-19, respectively. These results are in conformity with the results of Reddy *et al*. (2001), Chetan *et al.* (2013), Rathore *et al*. (2017), Chavan *et al.* (2021).

Akhauri and Yadav (2002) found that the larval population of the spotted pod borer fluctuated widely in relation to seasonal changes beginning from the second week of October till the end of December. The

Table 5. Correlation between weather parameters and spotted pod borer (*M. vitrata*) larvae per five plants during 2017-18. Where, Tmax: Maximum temperature RH-II: Evening relative humidity, WS: Wind speed Epan: Pan evaporation * Significant at 0.05% level , Tmin: Minimum temperature RH-I: Morning relative humidity, RF: Rainfall, BSS: Bright sunshine hours, ** Significant at 0.01% level.

Treatments		r' values							
Sowing window	Variety	Tmax	Tmin	RH-I	RH-II	Wind speed	Rainfall	Epan	BSS
D_1- 24th MW	V_1- Vipula	0.131	-0.417	0.383	-0.601*	-0.234	-0.253	-0.001	0.517*
D_2- 26th MW	V_1- Vipula	-0.017	-0.603*	0.410	-0.640*	-0.195	-0.360	-0.086	0.541*
D_3- 28th MW	V_1- Vipula	-0.065	-0.467	0.295	-0.454	-0.087	-0.373	-0.141	0.393
D_4- 30th MW	V_1- Vipula	-0.061	-0.441	0.293	-0.389	-0.119	-0.334	-0.190	0.330
D_1- 24th MW	V_2 - Rajeshwari	0.187	-0.320	0.322	-0.540*	-0.253	-0.152	0.061	0.468
D_2- 26th MW	V_2 - Rajeshwari	0.114	-0.432	0.374	-0.595*	-0.253	-0.244	-0.015	0.499
D_3- 28th MW	V_2 - Rajeshwari	-0.101	-0.506*	0.296	-0.434	-0.080	-0.399	-0.196	0.387
D_4- 30th MW	V_2 - Rajeshwari	-0.023	-0.438	0.311	-0.428	-0.135	-0.348	-0.147	0.369
D_1- 24th MW	V_3 - BDN 711	0.088	-0.478	0.382	-0.642**	-0.185	-0.318	0.045	0.559*
D_2- 26th MW	V_3 - BDN 711	-0.002	-0.539*	0.356	-0.593*	-0.190	-0.339	-0.109	0.498
D_3- 28th MW	V_3 - BDN 711	-0.018	-0.422	0.308	-0.406	-0.128	-0.325	-0.154	0.366
D_4- 30th MW	V_3 - BDN 711	-0.087	-0.513*	0.305	-0.462	-0.110	-0.393	-0.189	0.395
D_1- 24th MW	V_4 - ICPH 2740	0.114	-0.251	0.117	-0.345	-0.022	-0.251	0.141	0.340
D_2- 26th MW	V_4 - ICPH 2740	-0.008	-0.376	0.123	-0.366	0.004	-0.380	-0.010	0.355
D_3- 28th MW	V_4 - ICPH 2740	-0.020	-0.352	0.082	-0.336	0.047	-0.360	-0.063	0.305
D_4- 30th MW	V_4 - ICPH 2740	-0.047	-0.354	0.067	-0.336	0.080	-0.366	-0.054	0.306

period of maximum activity was between second and last week of November, when the mean population were fluctuated around 12.67 to 15.17 larvae plant^{-1} in pigeonpea.

Chetan *et al*. (2013) from Bangalore (Karnataka) studied that crop I, the larval incidence of *M. vitrata* commenced after 3rd week of September with 0.11 larvae plant^{-1} and gradually increased and attained a peak of 3.56 larvae plant^{-1} during the last week of October. In crop II, the infestation was started in 1st week of November and showed an upward trend from mid-December to mid-January 2011 with 3.49 larvae plant^{-1}. These results are accordance with present

Table 6. Correlation between weather parameters and spotted pod borer (*M. vitrata*) larvae per five plants during 2018-19. Where, Tmax: Maximum temperature, RH-II: Evening relative humidity, WS: Wind speed, Epan: Pan evaporation, * Significant at 0.05% level. min: Minimum temperature, RH-I: Morning relative humidity, RF: Rainfall, BSS: Bright sunshine hours, ** Significant at 0.01% level.

Treatments		r' values							
Sowing window	Variety	Tmax	Tmin	RH-I	RH-II	Wind speed	Rainfall	Epan	BSS
D_1- 24th MW	V_1- Vipula	0.557*	-0.081	-0.234	-0.621*	-0.315	-0.236	0.490	0.457
D_2- 26th MW	V_1- Vipula	0.420	-0.257	-0.139	-0.640*	-0.427	-0.313	0.358	0.465
D_3- 28th MW	V_1- Vipula	0.302	-0.232	-0.096	-0.522*	-0.428	-0.330	0.274	0.337
D_4- 30th MW	V_1- Vipula	0.172	-0.336	-0.005	-0.516*	-0.499*	-0.373	0.124	0.315
D_1- 24th MW	V_2 - Rajeshwari	0.706**	0.111	-0.281	-0.561*	-0.235	-0.061	0.645**	0.431
D_2- 26th MW	V_2 - Rajeshwari	0.520*	-0.156	-0.109	-0.655**	-0.428	-0.267	0.410	0.427
D_3- 28th MW	V_2 - Rajeshwari	0.208	-0.308	-0.045	-0.521*	-0.457	-0.391	0.172	0.320
D_4- 30th MW	V_2 - Rajeshwari	0.320	-0.193	-0.066	-0.519*	-0.408	-0.331	0.288	0.301
D_1- 24th MW	V_3 - BDN 711	0.578*	-0.040	-0.255	-0.587*	-0.294	-0.178	0.531*	0.465
D_2- 26th MW	V_3 - BDN 711	0.439	-0.249	-0.082	-0.650**	-0.463	-0.299	0.318	0.432
D_3- 28th MW	V_3 - BDN 711	0.136	-0.366	-0.035	-0.514*	-0.459	-0.435	0.099	0.331
D_4- 30th MW	V_3 - BDN 711	0.106	-0.377	0.057	-0.515*	-0.492	-0.436	0.069	0.280
D_1- 24th MW	V_4 - ICPH 2740	0.655**	0.293	-0.372	-0.313	-0.001	-0.114	0.704**	0.325
D_2- 26th MW	V_4 - ICPH 2740	0.436	0.069	-0.331	-0.351	-0.085	-0.318	0.531*	0.406
D_3- 28th MW	V_4 - ICPH 2740	0.183	0.027	-0.184	-0.120	-0.022	-0.294	0.352	0.158
D_4- 30th MW	V_4 - ICPH 2740	0.032	-0.124	-0.142	-0.224	-0.067	-0.440	0.244	0.269

Table 7. Forewarning models for one week prior (W-1) for prediction of spotted pod borer (*M. vitrata)* on pigeonpea larvae during 2017-18 and 2018-19.

Treatments Sowing window	Variety	Forewarning model	R^2 value
D_1- 24th MW	Vipula	Y= 4.239+2.741(T_{max}) – 0.519 T_{min}) – 0.435 (RH I)– 0.392 (RH II) – 0.023 (Rainfall) – 2.412(BSS)	0.552
D_2- 26th MW	Vipula	Y= 0.001+5.147 (T_{max}) –2.075 (T_{min})– 0.859 (RH I) – 0.220(RH II) – 0.067 (Rainfall) – 3.953(BSS)	0.517
D_3- 28th MW	Vipula	Y=- 6.952 + 8.814 (T_{max}) – 2.843 (T_{min})– 0.857 (RH I)– 0.066(RH II)– 0.111(Rainfall) –4.921(BSS)	0.727
D_4- 30th MW	Vipula	Y= - 19.430 + 5.447 T_{max}) – 2.828(T_{min}) -0.690 (RH I)+ 032(RH II)– 0.099 (Rainfall) – 4.567(BSS)	0.540
D_1- 24th MW	Rajeshwari	Y= 71.112 + 0.928 (T_{max}) – 0.161(T_{min}) – 0.659(RH I) – 0.528(RH II) +0.070(Rainall)-1.036(BSS)	0.759
D_2- 26th MW	Rajeshwari	Y= 68.869+ 2.207 (T_{max}) – 1.294(T_{min}) -0.748 (RH I) – 0.468 (RH II)+0.042 (Rainfall) –2.611(BSS)	0.773
D_3- 28th MW	Rajeshwari	Y= 69.134 + 3.342 (T_{max}) – 2.927(T_{min}) – 0.929(RH I) – 0.096(RH II)– 0.028 (Rainfall)– 3.586(BSS)	0.826
D_4- 30th MW	Rajeshwari	Y= 54.054+3.213 (T_{max}) – 2.533 (T_{min}) – 0.845(RH I) + 0.107(RH II)+ 0.001(Rainfall) –3.132(BSS)	0.803
D_1- 24th MW	BDN 711	Y= 38.748+1.856 (T_{max}) – 0.252(T_{min}) – 0.499(RH I) – 0.577 (RH II) – 0.000 (Rainfall)–1 .934(BSS)	0.637
D_2- 26th MW	BDN 711	Y= 10.482 +5.286 (T_{max}) – 2.568 (T_{min}) – 0.871 (RH I) – 0.262(RH II) – 0.018 (Rainfall) –.84(BSS)	0.648
D_3- 28th MW	BDN 711	Y= 6.327 +5.894 (T_{max}) – 3.609 (T_{min}) – 0.896 (RH I) – 0.032(RH II)– 0.058 (Rainfall)– 4.938(BSS)	0.790
D_4- 30th MW	BDN 711	Y= 0.496+4.799 (T_{max}) – 3.049 (T_{min}) – 0.616 (RH I) – 0.038 (RH II)– 0.069 (Rainfall)– 4.399(BSS)	0.728
D_1- 24th MW	ICPH 2740	Y= 1.623+ 3.383 (T_{max}) – 1.058 (T_{min}) – 0.428 (RH I) - 0.357 (RH II)– 0.039 (Rainfall)– 3.234(BSS)	0.520
D_{2-} 26th MW	ICPH 2740	Y= 11.499+ 4.917 (T_{max}) – 2.377 (T_{min}) – 0.809(RH I) – 0.191(RH II) – 0.100 (Rainfall)–4.496(BSS)	0.885
D_3- 28th MW	ICPH 2740	Y= -46.729–5.992 (T_{max}) – 3.397 (T_{min}) – 0.486(RH I)+0.161(RH II) – 0.120 (Rainfall)– 4 974(BSS)	0.543
D_4- 30th MW	ICPH 2740	Y=- 22.872–4 .309 (T_{max}) – 2.574 (T_{min}) – 0.361(RH I)+0.053(RH II) – 0.112 (Rainfall)– 3.999(BSS)	0.529

findings.

Correlation between weather parameters and population of spotted pod borer *M. vitrata* larvae on different pigeonpea varieties at different sowing windows and forewarning models for prediction of incidence of spotted pod borer *M. vitrata*

The influence of different weather parameters viz., maximum and minimum temperature, morning and evening relative humidity, wind speed evaporation and rainfall on the seasonal population of *M. vitrata* larva per five plants was observed by working out correlation coefficient (r) (Tables 5, 6) and forewarning models were developed are given in Table 7.

Results of the cumulative correlation showed that the population of spotted pod borer was found to have significant and positively correlation with maximum temperature, wind speed, pan evaporation and bright sunshine hrs. It was significant negative correlated with minimum temperature and evening relative humidity. On the basis of different sowing windows and varieties, the incidence of M. vitrata with weather factors was studied.

Correlation between weather parameters and population of spotted pod borer *M. vitrata* larvae on different pigeonpea var Vipula at different sowing windows and forewarning models for prediction of population of spotted pod borer (*M. vitrata*)

During first sowing window 24th MW (D_1) with var Vipula the population of *M. vitrata* larvae per five plants for one week prior (W-1) was significantly positive correlated with maximum temperature (0.131 and 0.557*) and bright sunshine hrs (0.517* and 0.457), whereas, it was negative correlated with minimum temperature (-0.417 and -0.081), evening relative humidity (-0.601* and -0.621*), wind speed (-0.234 and -0.315) and rainfall (-0.253 and -0.236) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var Vipula and D_1 sowing window (24th MW). The results obtained are given as follows.

The multiple regression equation is given below: Y= 4.239+ 2.741(T_{max}) – 0.519 (T_{min}) – 0.435 (RH I) – 0.392(RH II) – 0.023(Rainfall) – 2.412 (BSS).

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 2.741 units to an extent of 55.2% (R^2=0.552).

During second sowing window 26th MW (D2) with var Vipula the population of *M. vitrata* larvae per five plants for one week prior (W-1) was significant positively correlated with bright sunshine hrs (0.541* and 0.465), whereas, it was negative correlated with minimum temperature (-0.603* and -0.257), evening relative humidity (-0.647 and -0.640*), wind speed (0.234 and 0.427) and rainfall (-0.360 and -0.313) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *H. armigera* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var Vipula and D_2 sowing window (26th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= 0.001 + 5.147(T_{max}) – 2.075(T_{min}) – 0.859 (RH I) – 0.220 (RH II) – 0.067 (Rainfall) – 3.953 (BSS)$$

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 5.147 to an extent of 51.7 % (R^2=0.517).

During third sowing window 28th MW (D_3) with var Vipula the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.393 and 0.337), whereas, it was negative correlated with minimum temperature (-0.467 and -0.232), evening relative humidity (-0.454 and -0.522*), wind speed (0.087 and -0.428) and rainfall (-0.373 and -0.330) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var Vipula and D_3 sowing window (28th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= -6.952+8.814 (T_{max})– 2.843(T_{min}) – 0.857 (RH I)– 0.066 (RH II)–0.111 (Rainfall) – 4.921(BSS)$$

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 8.814 to an extent of 72.7 % (R^2=0.727).

During fourth sowing window 30th MW (D_4) with var Vipula the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine (0.330 and 0.315), whereas, it was negative correlated with minimum temperature (-0.441 and -0.336), evening relative humidity (-0.389 and -0.516*), wind speed (-0.119 and -0.499*), rainfall (-0.334 and -0.373) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var Vipula and D_4 sowing window (30th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= 54.054+3.213(T_{max}) – 2.533(T_{min})– 0.845(RH I) + 0.107(RH II)+0.001(Rainfall)– 3.132 (BSS)$$

An increase of one unit of maximum temperature and rainfall increased the population of *M. vitrata* by 3.213 and 0.001 units, respectively. These weather parameters collectively increased the population of *M. vitrata* to an extent of 80.3 % (R^2=0.803).

Correlation between weather parameters and population of *M. vitrata* larvae per five plants on pigeonpea var BDN 711 at different sowing windows and forewarning models for prediction of incidence of *M. vitrata*.

During first sowing window 24th MW (D_1) with var BDN 711 the population of *M. vitrata* larvae per five plants for one week prior (W-1) was significantly positively correlated with maximum temperature (0.088 and 0.578*) and positively bright sunshine hrs (0.559* and 0.465), whereas, it was negative correlated with minimum temperature (-0.470 and -0.040), evening relative humidity (-0.642** and -0.587*), wind speed (0.185 and 0.294) and rainfall (-0.318 and -0.178) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var BDN 711 and D_1 sowing window (24th MW). The results obtained are given as follows.

The multiple regression equation is given below:

Y= 38.748+ 1.856 (T_{max})– 0.252 (T_{min})– 0.499(RH I)– 0.577 (RH II)–0.000 (Rainfall)– 1.934 (BSS)

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 1.856 units to an extent of 63.7 % (R^2=0.637).

During second sowing window 26th MW (D_2) with var BDN 711 the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.498 and 0.432), whereas, it was negative correlated with minimum temperature (-0.539* and -0.249), evening relative humidity (-0.593* and -0.650*), wind speed (-0.190 and 0.463) and rainfall (-0.339 and -0.399) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var BDN 711 and D_2 sowing window (26th MW). The results obtained are given as follows.

The multiple regression equation is given below:

Y= 10.482 +5.286(T_{max})–2.568 (T_{min})–0.871(RH I)–0.262(RH II) – 0.018(Rainfall) – 4.284(BSS)

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 5.286 units to an extent of 64.8 % (R^2=0.648).

During third sowing window 28th MW (D_3) with var BDN 711 the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.366 and 0.331), whereas, it was negative correlated with minimum temperature (-0.422 and -0.366), evening relative humidity (-0.406 and -0.514*), wind speed (-0.128 and -0.459) and rainfall (-0.325 and -0.425) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var BDN 711 and D_3 sowing window (28th MW). The results obtained are given as follows.

The multiple regression equation is given below:

Y= 6.327+ 5.894 (T_{max})–3.609 (T_{min})– 0.896 (RH I)– 0.032 (RH II) –0.058 (Rainfall) – 4.938 (BSS)

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 5.894 units to an extent of 79.0 % (R^2=0.790).

During fourth sowing window 30th MW (D_4) with var BDN 711 the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with morning relative humidity (0.305 and 0.057) and bright sunshine hrs (0.395 and 0.280), whereas, it was significant negative correlated with minimum temperature (-0.513* and -0.377), evening relative humidity (-0.462 and -0.515*), wind speed (-0.110 and -0.492) and rainfall (-0.178 and -0.436) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for varBDN 711 and D_4 sowing window (30th MW). The results obtained are given as follows.

The multiple regression equation is given below:

Y= 0.496+ 4.799 (T_{max})–3.049 (T_{min})–0.616(RH I) – 0.038 (RH II) – 0.069 (Rainfall) – 4.399 (BSS)

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 4.799 units to an extent of 72.8 % (R^2=0.728).

Correlation between weather parameters and population of *M. vitrata* larvae per five plants on pigeonpea var ICPH 2740 at different sowing windows and forewarning models for prediction of incidence of *M. vitrata*

During first sowing window 24th MW (D_1) with var ICPH 2740 the population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with maximum (0.106 and 0.655) bright sunshine hrs (0.340 and 0.325), whereas, it was negative correlated with evening relative humidity (-0.345 and -0.313), wind speed (-0.022 and -0.001) and rainfall (-0.251 and -0.114) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var ICPH 2740 and D_1 sowing window (24th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= 1.623 + 3.383 (T_{max}) –1.058 (T_{min})– 0.428(RH I)–0.357 (RH II)– 0.039 (Rainfall) – 3.234 (BSS)$$

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 3.383 units to an extent of 52.0 % (R^2=0.520).

During second sowing window 26th MW (D_2) with var ICPH 2740 the population of population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.355 and 0.406), whereas, it was negative correlated with evening relative humidity (-0.366 and-0.351) and rainfall (-0.380 and -0.318) during kharif seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var ICPH 2740 and D2 sowing window (26th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= 11.499 + 4.917 (T_{max}) – 2.377(T_{min})–0.809(RH I)–0.191(RH II) –0.100 (Rainfall)– 4.496 (BSS)$$

An increase of one unit of maximum temperature increased the population of *M. vitrata* by 4.917 units to an extent of 88.5 % (R^2=0.885).

During third sowing window 28th MW (D_3) with var. ICPH 2740 the population of population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.305 and 0.158), whereas, it was significant negative correlated with evening relative humidity (-0.336 and -0.120) and rainfall (-0.360 and -0.294) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var ICPH 2740 and D_3 sowing window (28th MW). The results obtained are given as follows.

The multiple regression equation is given below:

$$Y= –46.729–5.992(T_{max)}–3.397(T_{min})– 0.486 (RH I) +0.161 (RH II)– 0.120 (Rainfall)–4.974 (BSS)$$

An increase of one unit of evening relative humidity increased the population of *M. vitrata* by 0.161 units to an extent of 54.3 % (R2=0.543).

During fourth sowing window 30th MW (D_4) with var ICPH 2740 the population of population of *M. vitrata* larvae per five plants for one week prior (W-1) was positively correlated with bright sunshine hrs (0.306 and 0.269), whereas, it was significant negative correlated with minimum temperature (-0.354 and -0.124), evening relative humidity (-0.336 and 0.224) and rainfall (-0.366 and -0.440) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The overall linear multiple regression analysis was worked out between population of *M. vitrata* on pigeonpea of W0 week with weather parameters of one week prior (W-1) for var ICPH 2740 and D_4 sowing window (30^{th} MW). The results obtained are given as follows. The multiple regression equation is given below:

Y= –22.872–4.309 (T_{max})– 2.574 (T_{min})–0.361 (RH I) +0.053 (RH II)–0.112 (Rainfall)–3.999 (BSS)

An increase of one unit of evening relative humidity increased the population of *M. vitrata* by 0.053 units to an extent of 52.9 % (R^2=0.529).

Keval *et al*. (2018) revealed that regression coefficient of abiotic factors were highly influencing as parameters that governed the population fluctuation and contributed (R^2 = 0.839 and 0.902) 83.9 and 90.2 % variation in *M.vitrata* population during both the years, respectively in ICPL 87 and it was also found that one unit increase in maximum and minimum temperature would cause 0.732 and 1.020 unit increase in 2015 and 0.114 and 0.536 unit increase in the second year of study in the *M. vitrata* population. However, one unit increase in the other weather parameters like morning relative humidity, evening relative humidity and rainfall would cause 0.406 and 0.341, 0.160 and 0.036 and 0.032 and 0.002 unit decrease in the pest population during both the years of study, respectively. Similar results were reported by Akhauri *et al.* (1996), Rathore *et al.* (2017), Keval *et al.* (2018).

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