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Yield loss assessment and establishment of economic threshold level of *Maruca vitrata* in pigeonpea

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ABSTRACT

Yield loss assessment using insect density and chemical protection method was carried out along with establishing the economic injury level (EIL) and economic threshold level (ETL) for *M. vitrata* in pigeonpea under field conditions. Using the insect density method, the highest avoidable loss of 79.05 per cent was recorded in the treatment with eight larvae per plant and lowest (29.75%) in the treatment with two larvae per plant. The correlation between the larval infestation level and the pod damage, as well as with the seed damage was significantly positive (r=0.98). However, the correlation between larval infestation level per plant and seed yield, as well as with 100 seed weight was significantly negative (r=0.98 and 0.95, respectively). Using the chemical protection method, the avoidable yield losses due to *M. vitrata* in pigeonpea varied from 39.55–84.68 per cent, with the determinate *var*. 'MN–1' registering the highest (84.68%) avoidable loss and the lowest (39.55%) being in the indeterminate var. 'PAU 881'. On the basis of regression analysis and gain threshold, the EIL and ETL of *M. vitrata* in pigeonpea were determined as 5.58 and 4.19 webs per plant, respectively.

Key words: Avoidable losses, Economic injury level (EIL), Economic threshold level (ETL), *Maruca vitrata*, Pigeonpea.

Pigeonpea, *Cajanus cajan* (L.) Millsp. commonly known as redgram, *tur*, *arhar* is an erect and short–lived perennial shrub legume. It is a major pulse crop in the semi–arid tropics and subtropical farming systems (Sharma, 1998). More than 300 insect species infest pigeonpea inflicting significant damage (Lal and Singh, 1998). Among them, the major loss is inflicted by the spotted pod borer, *Maruca vitrata* (Lepidoptera: Crambidae) (Gopali *et al.* 2010). *Maruca vitrata* is a serious pest because of its extensive host range, destructiveness and distribution on pigeonpea, cowpea, mungbean, urdbean and field bean (Shanower *et al*. 1999). It causes damage by webbing tender leaf axils, flower buds, flowers and pods, thus forming clusters of flowers or pods on about 39 hosts (Ganpathy, 2010). In pigeonpea, *M. vitrata* is known to cause damage ranging from 9 to 51 per cent (Vishakantaiah and Jagadeesh Babu, 1980). Dharmasena *et al.* (1992) reported pod borer damage up to the tune of 84 per cent in pigeonpea. This pest has been the only responsible factor resulting in heavy losses in early and medium late maturing pigeonpea genotypes (Sahoo, 1995, Shanower *et al.* 1999). The damage varied between 12.4 to 71.2 per cent depending upon the number of larvae per plant in pigeonpea (Sharma *et al*. 2014). Damage due to *M. vitrata* also varies with respect to branching and podding pattern in pigeonpea. Lateef and Reed (1981) concluded that 56 per cent of indeterminate lines had < 50 per cent damage in contrast to 15 per cent of the determinate lines and also suggested that the determinate types suffer more flower and pod damage by *M. vitrata.* Determinate genotypes of pigeonpea, where pods are clustered together at the top of the plant, are more prone to damage as compared to the indeterminate ones (Saxena *et al.* 1996). The change in pest complex is such that those insects which were earlier found to be sporadic, minor or non–injurious to these crops (such as *M. vitrata*), have become predominant pests in certain agro climatic conditions today, whereas other insects which were never previously recorded on these crops are now becoming a matter of concern (Taggar *et al.* 2012). This kind of shift in the pest complex necessitates systematic scientific investigations of the pest complex and economic loss assessment to determine the relative importance of insect pests

The concept of economic injury level (EIL) was first articulated by Stern *et al.* (1959) who defined it as the lowest population density that will cause economic damage. Vinayaka (2012) estimated the ETL of *M. vitrata* to be 0.54 larvae per plant in pigeonpea. Zahid *et al.* (2008) worked out the ETL of *M. vitrata* to be at 0.75 and 0.87 larvae per m row in mungbean during 2005–06 and 2006–07, respectively. Economic thresholds provide guidelines that help farmers determine when insecticides are economically justified, that is when the pest population is large enough to create economic damage (Pedigo *et al.* 1986). Hence, estimation of economic threshold level of the pest is of immense importance for rational use of insecticides.

MATERIALS AND METHODS

Insect density method: The assessment of avoidable yield losses due to *M. vitrata* in pigeonpea was carried out using insect density method. Insect density and yield loss relationships were studied as per the method of Sharma and Franzmann (2000) with some modifications. Three pigeonpea plants were randomly selected from each replication and infested with different larval infestation levels of 0, 2, 4, 6, and 8 third-instars of *M. vitrata* at the initiation of flowering stage. Uninfested plants (0 larval infestation level) served as untreated control. Each set of plants (including uninfested control) were covered with a white nylon cloth bag so as to prevent any external pest incidence. The larvae were released inside the cloth bag and the lower end of each bag was tied with a piece of twine. The cloth bags were removed three weeks after infestation to record further observations.

Chemical protection method: Based on the chemical protection method, field experiment was conducted to estimate yield losses due to *M. vitrata* in pigeonpea. For this, two indeterminate varieties ('PAU 881' and 'AL 201') and two determinate varieties ('AL 15' and 'MN 1') of pigeonpea were sown under protected and unprotected conditions with eight (four protected plots and four unprotected plots) treatments and four replications as per the recommended agronomic practices using randomized block design (RBD). Plants of each variety were sown in individual plots measuring 10 sq. m (4 rows of 5 m row length). Under protected conditions, foliar spray of recommended insecticide indoxacarb 14.5 SC @ 500 ml ha^{-1} was carried out at flowering stage of the crop. Unprotected plots were kept free from any insecticides and subjected to natural infestation of the pod borer.

The observations pertaining to the number of webs, pod damage and seed damage were recorded to estimate the avoidable yield losses by both insect density and chemical protection method. The number of webs produced per plant was counted from three tagged plants (protected and unprotected) per replication in each treatment for a period of three weeks. The observations on pod damage were recorded by counting the total number of pods and number of pods damaged by the pod borer from three tagged plants (protected and unprotected) per replication per treatment and converted into percentage. The seed damage was estimated by counting the total number of seeds per pod and number of seeds damaged by *Maruca* from 100 pods collected and converted into percentage. Seed yield of the protected and unprotected plants (g) was calculated after harvesting and threshing of the crop and converted into kg ha^{-1} to calculate avoidable yield loss. Weight of 100 grains from each treatment was recorded. Weight of three such grain samples from each of the four replications per treatment was taken and average was worked out. Per cent avoidable yield loss was worked out as per Pradhan (1964):

$$\text{Avoidable yield loss (\%)} = \frac{\text{Seed yield of protected plot (kg ha}^{-1}\text{) - Seed yield of unprotected plot (kg ha}^{-1}\text{)}}{\text{Seed yield of protected plot (kg ha}^{-1}\text{)}} \times 100$$

Economic injury level (EIL) and economic threshold level (ETL) of M. vitrata in pigeonpea: For establishing the economic injury level and economic threshold level of *M. vitrata*, pigeonpea var. 'PAU 881' was sown as per the recommended agronomic practices in plots measuring 5 m × 2 m in size in four replications using randomized block design (RBD). Three plants from each plot were tagged and four third-instar larvae of *M. vitrata* were released on each of the tagged plants at the initiation of flowering stage. Uninfested tagged plants served as untreated control. Tagged plants (including uninfested control) were covered with a white nylon cloth bag and the lower end of each such bag was tied with a piece of twine to avoid natural infestation. The bottom edges of the nylon cloth bags were inserted into the soil in all the sides to check the escape or entry of larvae. The larvae were allowed to feed on the plants till the formation of a known number of webs (1, 3, 5 and 7 webs per plant). As soon as a particular number of webs per plant were produced upon feeding, the tagged plants (except uninfested plants) were sprayed with the recommended insecticide (indoxacarb 14.5 SC @ 500 ml ha^{-1}) to control the pest. Seed yield of the infested and uninfested plants (g) was calculated and yield loss per plant was calculated using the formula:

$$\text{Yield loss per plant} = \frac{\text{Seed yield of uninfested plant (g) - Seed yield of infested plant (g)}}{\text{Seed yield of uninfested plant (g)}}$$

Yield loss per plant (g) was then converted into kg ha^{-1} to work out EIL and ETL values. For determination of economic injury level (EIL), the parameters like number of webs per plant, cost of plant protection, yield loss and average market price of the produce were taken into consideration. The regression coefficient 'b' between the two parameters, namely number of webs per plant (x) and yield loss (kg ha^{-1}) (y) and the regression model was calculated by using the following formula:

$$\text{Regression coefficient (b)} = \frac{\Sigma xy - \Sigma x \,.\, \Sigma y / N}{\Sigma x^2 - (\Sigma x)^2 / N}$$

where 'N' is the total number of observations

'x' is number of webs per plant and

'y' is the yield loss per plant (kg ha^{-1})

The EIL was computed by using the procedure given by Stone and Pedigo (1972) and further modified by Ogunlana and Pedigo (1974) as given below:

$$\text{Gain threshold} = \frac{\text{Cost of management (Rs. ha}^{-1}\text{)}}{\text{Market value of grains (Rs. kg}^{-1}\text{)}}$$

$$\text{Economic injury level} = \frac{\text{Gain threshold}}{\text{Regression coefficient}}$$

The economic threshold was estimated as 75 per cent of the EIL values (Pedigo 1991).

RESULTS

Avoidable yield loss due to M. vitrata in pigeonpea based on insect density method: The results presented in the Table 1 revealed significant differences in the extent of plant damage at different levels of larval infestation. During I week, the number of *Maruca* webs ranged from 0.00–16.75 per plant at different larval densities. Significantly the highest number of webs (16.75) was recorded at larval density of eight larvae per plant as compared to 0.00 webs in the uninfested control. This was followed by the larval densities of six, four and two larvae per plant which recorded 10.75, 8.75, 5.50 webs per plant, respectively. There was a progressive increase in the number of webs per plant with each subsequent increase in the number of larvae released per plant. Similar trend was observed in number of webs per plant corresponding to larval infestation levels during II week (Table 1). The number of *Maruca* webs varied from 0.00–16.50 per plant at all the larval infestation levels including uninfested control. In the treatment comprising eight larvae per plant, significantly highest numbers of webs (16.50/plant) were observed as compared to 0.00 webs in the uninfected control. This treatment was followed by larval infestation levels of six, four and two larvae per plant which recorded 10.75, 9.00 and 5.75 webs per plant, respectively.

During the III week, the number of webs ranged from 0.00–13.25 per plant at all the larval infestation levels. Treatment with eight larvae per plant recorded significantly the maximum webs (13.25/plant), followed by six, four and two larvae per plant which registered 8.50, 6.25 and 3.00 webs per plant, respectively as compared to the uninfected control (0.00 webs/plant). However, the number of webs formed at six and four larvae per plant were found to be statistically at par with each other, but significantly higher than the uninfected control. The mean number of webs produced at different larval infestation levels over a period of three weeks varied from 0.00–15.50 per plant (Table 1). Significantly the highest numbers of webs (15.50/plant) were registered at larval infestation levels of eight larvae per plant. It was followed by the treatment comprising six and four larvae per plant which recorded 10.00 and 8.00 webs per plant, respectively, both being statistically at par with each other. However, the lowest numbers of webs (4.75/plant) were recorded at larval infestation level of two larvae per plant, whereas no webs were observed in the uninfected control.

Data pertaining to the pod damage recorded at different larval infestation levels of *M. vitrata* have been presented in Table 2. Pod damage was in the range of 0.00–18.98 per cent at all the larval infestation levels, including uninfected control. Significantly the highest pod damage was observed in the treatment with eight larvae per plant (18.98%), followed by six, four and two larvae per plant which recorded 11.46, 6.43 and 3.51 per cent pod damage, respectively, as compared to the uninfected control (no pod damage). Seed damage corresponding to different larval infestation levels varied in the range of 0.00–20.25 per cent (Table 2). Treatment with eight larvae per plant registered significantly highest seed damage (20.25%) and was statistically at par with the seed damage observed at six larvae per plant (18.25%). However, the seed damage observed at four and two larvae per plant was 13.25 and 8.25 per cent, respectively as compared to the uninfected control (no seed damage).

Significant variations were observed pertaining to the seed yield per plant at the different larval infestation levels (Table 2). The seed yield per plant was found to vary from 3.83–18.28 g per plant among all the treatments including uninfected control. The treatment with zero larval infestation (uninfected control) registered significantly highest seed yield of 18.28 g per plant, followed by two, four and six larvae per plant registering the seed yield of 12.84, 9.25 and 4.98 g per plant, respectively. However, the lowest seed yield was recorded in the treatment with highest larval infestation level of eight larvae per plant (3.83 g/

Table 1. Number of webs formed at different larval infestation levels densities of *Maruca vitrata* in pigeonpea

Number of larvae (per plant)	Number of webs per plant*			Mean webs per plant
	I week	II week	III week	
0 (Uninfested control)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	**0.00 (1.00)**
2	5.50 (2.52)	5.75 (2.57)	3.00 (1.97)	**4.75 (2.38)**
4	8.75 (3.11)	9.00 (3.15)	6.25 (2.68)	**8.00 (2.99)**
6	10.75 (3.39)	10.75 (3.41)	8.50 (3.06)	**10.00 (3.31)**
8	16.75 (4.18)	16.50 (4.15)	13.25 (3.74)	**15.50 (4.05)**
CD (p=0.05)	**(0.66)**	**(0.61)**	**(0.53)**	**(0.37)**

Figures in parentheses are "n+1 transformed means
*Mean of four replications

Table 2. Effect of larval infestation levels of *Maruca vitrata* on pod damage, seed damage and seed yield of pigeonpea

Number of larva (per plant)	*Pod damage (%)	*Seed damage (%)	*Seed yield per plant (g)	*100 seed weight (g)	Avoidable yield losses (%)
0 (Uninfested control)	0.00 (1.00)	0.00 (1.00)	18.28	8.20	–
2	3.51 (10.77)	8.25 (3.03)	12.84	8.10	**29.75**
4	6.43 (14.66)	13.25 (3.75)	9.25	7.96	**49.39**
6	11.46 (19.72)	18.25 (4.38)	4.98	7.68	**72.75**
8	18.98 (25.80)	20.25 (4.60)	3.83	7.25	**79.05**
CD (p = 0.05)	**(1.64)**	**(0.33)**	**0.18**	**0.70**	–

Figures in parentheses are arc sine transformed means
*Mean of four replications

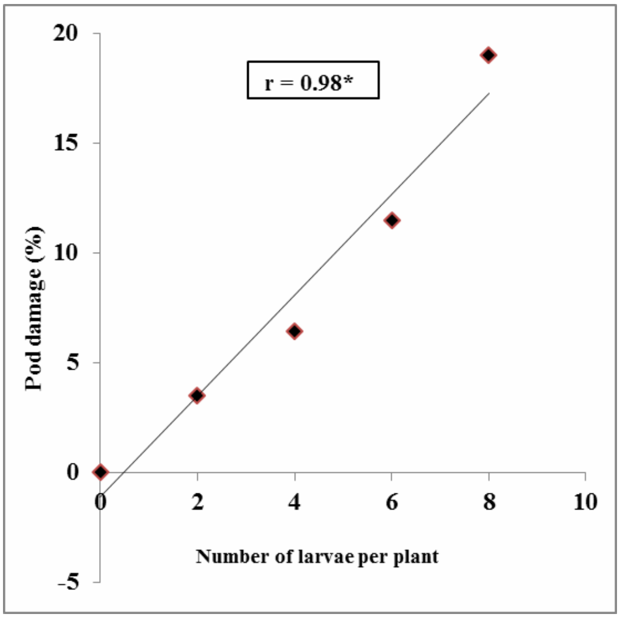

Figure 1. Correlation between *M. vitrata* larval infestation levels and pod damage in pigeonpea (*Significant at 1% level of significance)

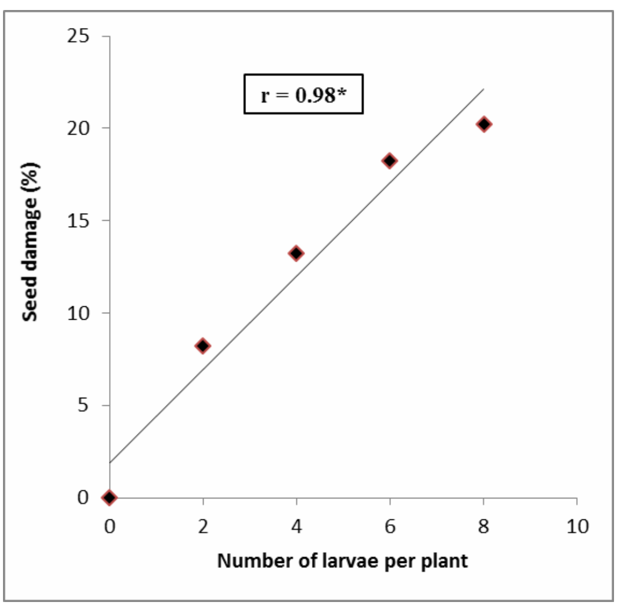

Figure 2. Correlation between *M. vitrata* larval infestation levels and seed damage in pigeonpea (*Significant at 1% level of significance)

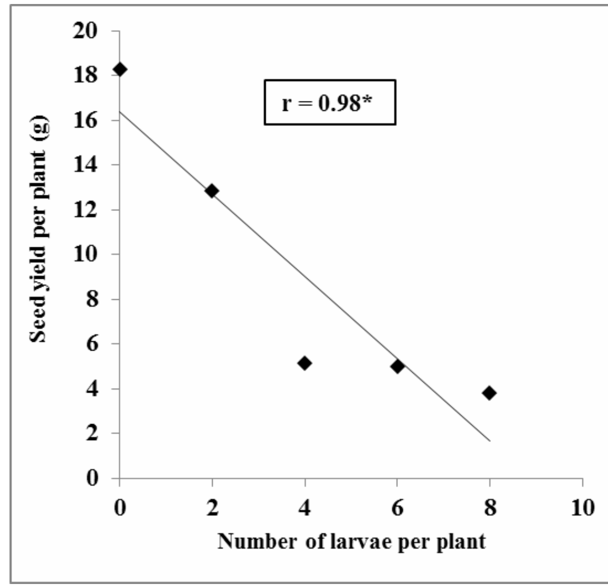

Figure 3. Correlation between *M. vitrata* larval infestation levels and seed yield in pigeonpea (*Significant at 1% level of significance)

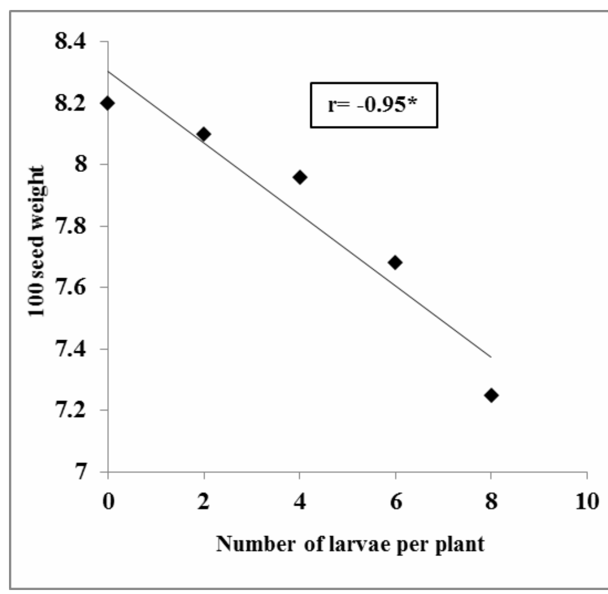

Figure 4. Correlation between *M. vitrata* infestation levels and 100 seed weight in pigeonpea (*Significant at 1% level of significance)

plant). With the increasing larval infestation level, the 100 seed weight (g) was found to reduce progressively. The 100 seed weight ranged from 7.25–8.20 g in all the treatments including uninfected control. The uninfected control treatment (8.20 g) recorded significantly the highest 100 seed weight as compared to two (8.10 g), four (7.96 g) and six (7.68 g) larvae per plant. However, all of the above three treatments were statistically at par with each other. Treatment with eight larvae per plant registered the lowest 100 seed weight (7.25 g) among all the treatments.

The perusal of the data in (Table 2) revealed that avoidable yields losses in pigeonpea var. 'PAU 881' due to *M. vitrata* increased with every subsequent increase in the larval infestation level. The treatment with eight larvae per plant recorded the highest avoidable yield loss of 79.05 per cent, followed by six and four larvae per plant registering yield losses of 72.75 and 49.39 per cent, respectively. However, the lowest avoidable yield loss (29.75%) was recorded in treatment with two larvae per plant among all the treatments.

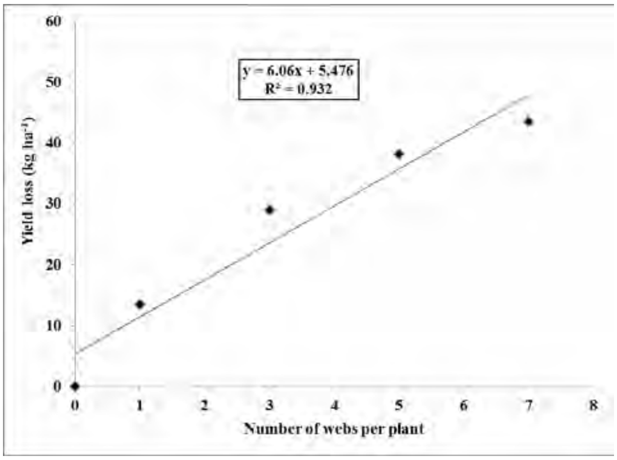

Figure 5. Regression equation between yield loss due to *M. vitrata* and number of webs per plant in pigeonpea

The correlation coefficients for larval infestation levels of *M. vitrata* were worked out with pod damage, seed damage, seed yield and 100 seed weight (Fig. 1-4). The correlation between the larval infestation levels and the pod damage (%) as well as with the seed damage (%) was significantly positive (r=–0.98) (Figure 1 and 2). On the other hand, as depicted in Figure 3 & 4, the correlation between larval infestation levels per plant and seed yield (%) as well as with 100 seed weight (g) was significantly negative (r=–0.98 and –0.95, respectively).

Avoidable yield losses due to M. vitrata in pigeonpea using chemical protection method: The data presented in (Table 3) depict the variation in the number of *Maruca* webs produced per plant in four varieties of pigeonpea protected as well as unprotected recorded over a period of three weeks. The pooled mean pertaining to the webs formed by *M. vitrata* during the period of three weeks revealed that the number of webs formed varied in the range of 6.04–17.09 per plant in all the treatments with the determinate var. 'MN–1' recording significantly highest number of webs (17.09 webs/plant), followed by 'AL 15' (13.44 webs/plant). However, the indeterminate var. 'PAU 881' and 'AL 201' recorded significantly lowest mean webs of 6.04 and 7.41 per plant, respectively. The unprotected treatment (UP) recorded significantly highest number of mean webs (13.76/plant) as compared to protected treatment (P) with 8.22 webs per plant. Interaction studies revealed that there were significant differences in the pooled mean of number of webs per plant produced during three weeks among different pigeonpea varieties and spray treatments (P and UP). Under protected conditions, the infestation of *M. vitrata* was found to vary from 3.24–13.96 webs per plant. The indeterminate var. 'MN–1' recorded significantly highest number of webs (13.96/plant), followed by another determinate var. 'AL 15' (11.52 webs/plant) under protected conditions. However, the indeterminate var. 'PAU 881' and 'AL 201' recorded comparatively lower number of webs of 3.24 and 4.16 webs per plant, respectively. Under unprotected conditions, the infestation of *M. vitrata* varied in the range of 8.83–20.22 webs per plant, with determinate var. 'MN–1' recording significantly highest number of webs (20.22/plant) as compared to other varieties, followed by 'AL 15' registering 15.35 webs per plant. However, the indeterminate var. 'PAU 881' recorded significantly least number of *Maruca* webs (8.83/plant), followed by another indeterminate var. 'AL 201' (10.66 webs/plant).

The pod damage pertaining to all the four pigeonpea varieties ranged from 13.44–30.23 per cent under both protected and unprotected conditions (Table 4). Significantly highest mean pod damage (30.23%) was registered in the determinate var. 'MN–1', followed by 'AL 15' (24.71% mean pod damage). However, the indeterminate varieties, *viz*. 'PAU 881' and 'AL 201' registered 13.44 and 15.61 per cent mean pod damage, respectively and both were found to be statistically at par with each other. The varieties under unprotected treatment registered significantly highest mean pod damage (27.35%) as compared to 14.65 per cent in protected treatment. Interaction studies suggested that the differences in the pod damage among different pigeonpea varieties and spray treatments were also statistically significant. The pod damage caused by *M. vitrata* in different pigeonpea genotypes varied from 8.86–36.14 per cent under both protected and unprotected conditions. The indeterminate

Table 3. Infestation of *Maruca vitrata* in different pigeonpea varieties under protected and unprotected conditions

Variety		Number of webs per plant*											Mean
		I Week		Mean	II Week		Mean	III Week		Mean	Pooled Mean		
		P	UP		P	UP		P	UP		P	UP	
PAU 881		3.00	4.41	3.70	3.33	11.08	7.20	3.41	11.00	7.20	3.24	8.83	6.04
AL 201		2.33	5.50	3.91	5.33	13.25	9.29	4.83	13.25	9.04	4.16	10.66	7.41
AL 15		8.25	10.83	9.54	14.08	17.91	15.99	12.25	17.33	14.79	11.52	15.35	13.44
MN–1		12.58	16.75	14.67	14.16	21.33	17.74	15.16	22.58	18.87	13.96	20.22	17.09
Mean		6.54	9.37		9.22	15.89		8.91	16.04		8.22	13.76	
CD (p=0.05)	Variety	0.73			1.76			2.04			0.88		
	P/UP	0.52			1.24			1.44			0.62		
	Var. ×P/UP	1.04			NS			NS			1.25		

*Mean of four replications, P: Protected, UP: Unprotected

Table 4. Damage potential of *Maruca vitrata* in different pigeonpea varieties under protected and unprotected conditions

Variety		*Pod damage (%)			*Seed damage (%)		
		P	UP	Mean	P	UP	Mean
PAU 881		9.19	17.69	13.44	4.31	10.40	7.35
AL 201		8.86	22.37	15.61	4.81	11.99	8.40
AL 15		16.24	33.18	24.71	8.11	15.78	11.94
MN–1		24.32	36.14	30.23	10.02	20.58	15.30
	Mean	14.65	27.35		6.81	14.68	
	Variety	2.52			2.00		
CD	P/UP	1.78			1.41		
(p = 0.05)	Var. × P/UP	3.56			NS		

*Mean of four replications, P: Protected, UP: Unprotected

var. 'AL 201' registered significantly lowest pod damage (8.86%), which was at par with 'PAU 881' (9.19% pod damage). The determinate varieties, *viz.* 'AL 15' and 'MN–1' recorded significantly higher pod damage of 16.24 and 24.32 per cent, respectively under protected condition. However, under the unprotected condition, comparatively higher pod damage of 36.14 and 33.18 per cent was recorded in both the determinate varieties 'MN–1' and 'AL 15', respectively; both being statistically at par with each other. The other two indeterminate varieties, 'PAU 881' and 'AL 201' recorded pod damage of 17.69 and 22.37 per cent, respectively under unprotected condition.

The results pertaining to the seed damage caused by *M. vitrata* in different pigeonpea varieties under protected and unprotected conditions have been presented in Table 4. The mean seed damage ranged from 7.35–15.30 in all the four varieties, with the indeterminate var. 'PAU 881' recording significantly lowest mean seed damage (7.35%), followed by 'AL 201' (8.40%). However, both these treatments were statistically at par with each other. On the other hand, the determinate varieties 'AL 15' and 'MN–1' recorded mean seed damage to the extent of 11.94 and 15.30 per cent, respectively. Different pigeonpea varieties under unprotected treatment recorded significantly highest seed damage (14.68%) as compared to those under the protected treatment (6.81%). However, interaction studies revealed that there were non–significant differences pertaining to the seed damage among all the four varieties under protected and unprotected conditions.

The results presented in (Table 5) revealed significant differences in the seed yield of four varieties of pigeonpea (protected as well as unprotected). The mean seed yield varied from of 407–996 kg ha^{-1} in all the four pigeonpea varieties. Significantly highest mean seed yield was recorded in the indeterminate var. 'AL 201' (996 kg ha^{-1}), followed by the other indeterminate var. 'PAU 881' (984 kg ha^{-1}), both being statistically at par with each other. However, the mean seed yield in the determinate var. 'MN-1' was significantly lowest registering 407 kg ha^{-1} of mean seed yield, followed by determinate var. 'AL 15' (836 kg ha^{-1} of mean seed yield). Significant differences were observed in the mean seed yield recorded under protected as well as unprotected conditions. In the protected treatment, significantly higher mean seed yield of (1062 kg ha^{-1}) was recorded as compared to the unprotected treatment which recorded as low as 549 kg ha^{-1} of mean seed yield. Interaction studies revealed that the differences in the seed yield (kg ha^{-1}) among different pigeonpea varieties and spray treatments were also statistically significant. The seed yield recorded in all the four varieties under protected condition ranged from 108–1236 kg ha^{-1}. Under protected condition (P), significantly highest seed yield was recorded in the indeterminate var. 'AL 201' (1236 kg ha^{-1}) which was statistically at par with the other indeterminate var. 'PAU 881' (1226 kg ha^{-1}). On the other hand, the determinate varieties 'AL 15' and 'MN–1' recorded comparatively lower seed yield of 1080 and 705 kg ha^{-1} under protected condition, respectively. In the unprotected condition, the seed yield of different varieties varied from 108–756 kg ha^{-1}. However, the indeterminate varieties 'AL 201' (756 kg ha^{-1}) and 'PAU 881' (741 kg ha^{-1}) were statistically at par with each other recording significantly higher seed yield as compared to the determinate varieties 'AL 15' and 'MN–1' registering significantly lowest seed yields of 638 and 108 kg ha^{-1}, respectively under unprotected conditions.

Among the four pigeonpea varieties, the mean 100 seed weight was found to vary from 5.47–7.73 g (Table 5). Significantly the highest 100 seed weight of 7.73 g was

Table 5. Yield attributes of different pigeonpea varieties and avoidable yield loss due to *Maruca vitrata* under protected and unprotected conditions

Variety		*Seed yield per plant (g)			*Seed yield (kg ha^{-1})			*100 seed weight (g)			Avoidable yield loss (%)
		P	UP	Mean	P	UP	Mean	P	UP	Mean	
PAU 881		6.05	4.90	5.48	1226	741	984	8.10	7.35	7.73	39.55
AL 201		6.22	5.15	5.69	1236	756	996	6.80	6.30	6.55	38.83
AL 15		5.66	4.42	5.04	1080	592	836	6.52	5.59	6.06	45.18
MN–1		5.35	3.79	4.57	705	108	407	6.76	4.17	5.47	84.68
	Mean	5.82	4.56		1062	549		7.04	5.85		–
CD	Variety	0.74			47.17			0.82			–
(p=0.05)	P/UP	0.52			33.36			0.58			–
	Var.× P/UP	0.10			66.72			0.11			–

*Mean of four replications, P: Protected, UP: Unprotected recorded in the indeterminate variety 'PAU 881', followed by 6.55 g in var. 'AL 201'. The determinate varieties 'AL 15' and 'MN–1' recorded significantly lower 100 seed weight of 6.06 and 5.47 g, respectively. There were significant differences in the mean 100 seed weight under protected and unprotected conditions. The protected treatment (P) registered significantly higher mean 100 seed weight (7.04 g) as compared to the unprotected treatment (UP) with 5.85 g mean seed weight. Significant differences were observed in the 100 seed weight in all the four varieties of pigeonpea under protected as well as unprotected conditions, as suggested by interaction studies. The 100 seed weight recorded among all the four pigeonpea varieties under protected and unprotected conditions ranged from 4.17–8.10 g. In protected condition, 100 seed weight was found to be significantly highest in the indeterminate var. 'PAU 881' (8.10 g), followed by 'AL 201' (6.80 g). However, the 100 seed weight reduced to 6.76 and 6.52 g in the determinate varieties 'AL 15' and 'MN–1', respectively. Under unprotected condition, similar trend was observed with 'PAU 881' and 'AL 201' recording 7.35 and 6.30 g 100 seed weight, respectively. On the contrary, the determinate varieties 'AL 15' and 'MN–1' recorded comparatively lower 100 seed weight of 5.59 and 4.17 g, respectively.

The results pertaining to avoidable yield loss due to *M. vitrata* in four pigeonpea varieties using chemical protection method have been depicted in Table 5. The avoidable yield losses due to *M. vitrata* varied from 39.55–84.68 per cent among the different varieties of pigeonpea, with the determinate var. 'MN–1' registering the highest avoidable yield loss of 84.68 per cent as compared to the other varieties. The other determinate var. 'AL 15' recorded avoidable yield loss up to 45.18 per cent due to *M. vitrata*. However, the indeterminate varieties 'PAU 881' and 'AL 201' recorded lower avoidable yield losses up to 39.55 and 38.83 per cent, respectively.

Economic injury level (EIL) and economic threshold level (ETL) of M. vitrata in Pigeonpea: The results presented in Table 6 revealed that the yield loss of pigeonpea increased with an increase in the number of webs per plant. The yield losses in different treatments ranged from 13.52–43.52 kg ha^{-1}. The highest amount of reduction in the seed yield (43.52 kg ha^{-1}) was recorded in the treatment comprising of seven webs per plant. The treatments with three and five webs per plant recorded the yield reduction of 29.01 and 38.23 kg ha^{-1}, respectively. However, the least amount of reduction in seed yield (13.52 kg ha^{-1}) was noticed in treatment with one web per plant. No yield losses were observed in uninfested control.

In the present studies, the regression coefficient (b) between number of webs per plant (x) and yield loss (kg ha^{-1}) (y) was computed for 'N' number of observations. From the regression analysis, a regression equation of the form Y= 6.06x + 5.47 was obtained and the yield reduction per web was calculated to be 6.06 (Figure 5).

Table 6. Pod damage and yield loss in pigeonpea at different web numbers produced by *Maruca vitrata*

Webs per plant (x)	*Pod damage (%)	Yield loss (kg ha^{-1}) (y)	xy	x^2
0 (Uninfested control)	0.00 (1.00)	–	0	0
1	1.63 (6.91)	13.52	13.52	1
3	3.45 (10.70)	29.01	87.03	9
5	4.51 (12.26)	38.23	191.15	25
7	6.20 (14.41)	43.52	304.64	49
$\sum x = 16$	CD (p = 0.05) = (1.97)	$\sum y = 124.28$	$\sum xy =$ 596.61	$\sum x^2 = 84$

Figures in parentheses are the arc sine transformed means
*Mean of four replications

$$\text{Regression coefficient (b)} = \frac{\Sigma xy - \Sigma x.\Sigma y/N}{\Sigma x^2 - (\Sigma x)^2/N}$$

$$= \frac{596.61 - 16 \times 124.28/5}{84 - (16)^{'}/5}$$

$$= \frac{596.61 - 397.69}{84 - 51.2}$$

$$= \frac{198.92}{32.8}$$

$$= 6.06$$

Intercept y (a) = $\sum y/N - b$ åx/N

$= 124.28/5 - 6.06 \times 16/5$

$= 24.85 - 19.39$

$= 5.47$

Regression equation = $6.06x + 5.47$

$R^2 = 0.932$

The total cost (including daily wages) incurred for the management of the pest using the application of recommended insecticide indoxacarb 14.5 SC @ 500 ml ha^{-1} was calculated to be Rs.1710 ha^{-1}. The prevailing market price of pigeonpea produce was Rs. 50.50 kg^{-1}.

$$\text{Gain threshold} = \frac{\text{Cost of management (Rs. ha}^{-1})}{\text{Market value of grains (Rs. kg}^{-1})} = \frac{1710}{50.50} = 33.86$$

The economic injury level was computed by using the following formula given by Stone and Pedigo (1972):

$$\text{Economic injury level} = \frac{\text{Gain threshold}}{\text{Regression coefficient}} = \frac{33.86}{6.06} = 5.58$$

As per Pedigo (1991), the economic threshold was calculated as 75 per cent of the EIL values.

Economic threshold level = EIL × 0.75 = 5.58 × 0.75= 4.19

Hence, based on the above calculations, the EIL and ETL of *M. vitrata* in pigeonpea were determined as 5.58 and 4.19 webs per plant, respectively.

DISCUSSION

Based on insect density–yield relationship studies conducted by Sharma and Franzmann (2000), it was observed that more than eight larvae per plant of *M. vitrata* in pigeonpea caused considerable damage and losses in the grain yield to the tune of more than 50 per cent. However, 2–4 larvae per plant had no significant effects on the yield. Thus, the study was in conformity with the present findings where pod damage increased with progressive increase in the larval infestation level. Ganapathy (1996) determined the avoidable losses due to *M. testulalis* up to 50 per cent and flower drop damage to the extent of 9.4 to 12.7 per cent was observed in short, medium and long duration pigeonpea cultivars in Tamil Nadu. Mohapatra and Srivastava (2008) also estimated the losses caused by *M. vitrata* in pigeonpea and observed that the pod and seed damage and the yield loss were 43.1 and 74.7 kg ha^{-1}, respectively.

The present study highlights the fact that the extent of damage (both in terms of webbings and pod damage) by *M. vitrata* was higher in the determinate varieties of pigeonpea as compared to the indeterminate types. This is reflected from the greater number of webs formed per plant in the determinate varieties as compared those in the indeterminate varieties. The clustered inflorescences of the determinate pigeonpea plants are more conducive for construction of webs by the larvae. Therefore, *M. vitrata* was found to infest in greater numbers in these determinate varieties. Lateef and Reed (1981) also suggested that determinate types are more prone to flower and pod damage by *M. vitrata* than the indeterminate types having loose fruiting branches and inflorescences. Saxena *et al.* (2002) also reported that the determinate accessions of pigeonpea plants with clustered inflorescences were more prefered by *M. vitrata* for oviposition, webbing and larval growth, as compared to the long fruiting branches and loose inflorescence of the non–determinate ones. Further, the mean pod damage estimated in the determinate accessions was about 66–75 per cent, as compared to 41–50 per cent in the non–determinate accessions. Wubneh and Taggar (2016) observed that the determinate var. 'MN–1' recorded significantly highest web damage (2.77–16/plant) due to *M. vitrata* in pigeonpea and also registered significantly highest mean pod damage of 40.61 per cent, followed by another determinate var. AL 15 recording 32.48 per cent pod damage. Hence, the variations in the plant architecture, particularly the branching and flowering pattern influence the extent of *M. vitrata* infestation in pigeonpea to a great extent.

Scanty information is available on establishment of ETL of *M. vitrata* in pigeonpea. Sahoo and Senapati (2000) established the economic thresholds of the pod borer complex, particularly *M. vitrata* in pigeonpea to be 3.9 larvae per plant or 8.3 per cent pod damage. Vinayaka (2012) calculated ETL of *M. vitrata* in pigeonpea to be 0.54 larva per plant which is almost equal to one larva per two plants. Zahid *et al.* (2008) reported EIL and ETL values of *M. vitrata* to be 1.08 and 0.81 larvae per m row, respectively in mungbean. Ogunwolu (1990) determined the ETL of *M. testulalis* as 40 per cent larval infestation in flowers of cowpea. According to Nuradeen (2016), the EIL of *M. vitrata* in cowpea was 0.15 and 0.16 for both screen house and field cages, respectively, whereas Rekha (2005) worked out the economic injury level for pod borers including *M. vitrata* to be 0.45 larva per plant in dolichos bean.

According to Ghorbandi (1986), the factors influencing economic threshold include the variety and stage of crop, density and behaviour of pest, the beneficial insect population, kinds of control measures available, cost of managing the pest using chemical control, cost of produce, weather parameters and the aptitude of farmers towards the control technology. In the present investigation, the ETL of *M. vitrata* was found to be 4.19 webs per plant. Henceforth, the variation in the results of the present findings and the earlier reports may be due to any of the above factors. Presently, for the management of *M. vitrata* in pigeonpea, the application of insecticides at bud or flower initiation stage has been recommended to the farmers of Punjab (Anonymous 2017, Taggar *et al.* 2015). Based on the results of present research, pigeonpea growers across the state can take up the management of *M. vitrata* as and when the number of webs reaches 4.19 per plant. However, based on these preliminary studies, a comprehensive sampling plan for *M. vitrata* could be devised in pigeonpea. Such studies will not only help the farmers in reducing the cost of pest management, but will also help in rationalizing the insecticidal usage on the crop.

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