Original Research Article

Morphological basis of resistance in pigeonpea (*Cajanus cajan* (L.) Millsp.) against pod borer complex

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ABSTRACT

Field experiment was carried out to determine the morphological basis of resistance in pigeonpea against pod borer complex during *kharif* 2021-22, 2022-23 and 2023-24 at College of Agriculture, Navsari Agricultural University, Bharuch (Gujarat). Among the twelve pigeonpea genotypes/cultivars screened, BP-17-02 was found highly resistant and BP-16-182, BP-16-228, BP-16-261, ICPL-87119 and BP-16-166 were found resistant whereas, GNP-2 and Vaishali were found highly susceptible against pod borers. Genotypes/cultivars viz., BP-16-178, ICPL 87119, BP-16-182, BP-16-228 and BP-16-183 were found resistant to pod fly. Genotypes/cultivars having short pod length, narrow pod breadth, narrow seed breadth, more seeds/pod, more seed weight, more seed density, thick pod wall thickness and long trichome length recorded lower pod borers population. Pod length had a significant positive correlation with *Maruca vitrata, Exelastis atomosa* and *Melanagromyza obtusa*. Significant positive association was found between pod breadth and larval population of *Helicoverpa armigera* and *Maruca vitrata*. Significant negative correlation was found between *Exelastis atomosa* and pod wall thickness.

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Keywords: pigeonpea, *Maruca vitrata, Exelastis atomosa, Melanagromyza obtusa*, *Helicoverpa armigera*

1. INTRODUCTION

Pigeonpea or red gram or arhar is an important pulse crop in India, where it is next in importance after chickpea among different pulses. It is mostly grown under rainfed areas, where drought condition is a common feature. In India, pigeonpea is grown on 47.24 lakh ha area with a production of 43.16 lakh tonnes and a productivity of 914 kg/ ha. In Gujarat, pigeonpea is grown under 2.41 lakh ha area with an annual production of 2.86 lakh tonnes leading to a productivity of 1186 kg/ha [1]. The major pigeonpea growing states are Maharashtra, Uttar Pradesh, Karnataka, Gujarat and Andhra Pradesh that altogether account for more than 87 per cent area and 83 per cent of the production.

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The major constraints for the low productivity the pigeonpea are biotic and abiotic stresses. Among biotic stresses, Pod borers cause huge annual losses and damage to pods due to the borer complex was reported to be 20 to 72 per cent [2]. Most of the insect pests attack the crop at reproductive stage causing direct losses. More than 250 species of insects belonging to 8 orders and 61 families have been found to infest pigeonpea. Among them the pod borer, *Helicoverpa armigera* (Hubner); pod fly, *Melanagromyza obtusa* (Malloch); spotted pod borer, *Maruca vitrata* (Geyer); plume moth, *Exelastis atomosa* (May); blister beetle, *Mylabris spp*; pod sucking bugs; *Clavigralla spp* and the bruchids, *Callosobruchus spp* are the most important insect pests, causing damage to the pigeonpea crop [3]. Hence

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it is important to determine the morphological basis of resistance in pigeonpea. Use of morphological tolerant high yielding varieties can minimize the use of pesticides and can conserve natural enemies with low cost of production.

2. MATERIAL AND METHODS

Field experiment was conducted during *kharif* 2021-22, 2022-23 and 2023-24 at College of Agriculture, Navsari Agricultural University, Bharuch (Gujarat) to determine the morphological basis of resistance in pigeonpea against pod borer complex. Twelve promising genotypes/cultivars of pigeonpea were sown in Randomized Block Design with three replications in gross plot : 3.6 m x 2.0 m and Net plot :1.8 m x 1.6 m. Recommended crop spacing 90 cm x 20 cm was kept with recommended fertilizer dose of 25 :50 : 00 (N:P:K). Crop was raised successfully by adopting recommended agronomical practices. The whole plot was kept free from insecticide to allow pod borers to multiply throughout the season.

For recording observations on larval population of pod borers *i.e. Helicoverpa armigera* (gram pod borer), spotted pod borer (*Maruca vitrata*) and tur plume moth (*Exelastis atomosa*), 5 plants were randomly selected and tagged in each plot. The larval population of pod borers were counted at weekly interval commencing from bud initiation to removal of the crop. For recording damage due to pod fly (*Melanagromyza obtusa)*, 50 pods were collected from 5 plants from each plot and from these 250 pods, healthy and damage pods were counted separately for per cent pod fly damage. Categorization of genotypes/cultivars into resistant, highly resistant, susceptible and highly susceptible were done using the scale given by Patel *et al*.,[4].

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Category of resistance	**Scale for resistance**
Highly resistant	$\overline{X}_i < \overline{X} - SD$
Resistant	$\overline{X}_i > \overline{X} - SD < \overline{X}$
Susceptible	$\overline{X}_i > \overline{X} < (\overline{X} + SD)$
Highly susceptible	$\overline{X}_i > (\overline{X} + SD) < (\overline{X} + 2\ SD)$

The morphological characters *viz.,* pod length, pod breadth, seed weight, seed density, seed length and breadth, no. of seeds/pod, thickness of pod wall, trichome length and density of various pigeonpea cultivars were recorded using following standard methodology.

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2.1. Pod size

The length and breadth of 25 pods from each cultivar were measured with the help of standard scale. The average of the samples for each cultivar were calculated and recorded. The average length and breadth of pod were correlated with pod borers.

2.2. Thickness of pod wall

In order to measure the thickness of pod wall, 25 freshly plucked pigeonpea pods of 25 days age were randomly collected from each cultivar. The four-locute pods were chosen for cross section. The thickness of pod wall was measured with the help of Digital thickness gauge.

2.3. Number of seeds per pod

The number of seeds per pod were determined from randomly picked 25 pods from five plants of each cultivar at harvest. For this, number of locules unfilled as well as filled up with the seed were counted and recorded as number of seeds/pod.

2.4. Seed size and weight

The length and breadth of 25 seeds from each cultivar were measured after drying the seed under sun; with the help of Vernier caliper. The weight of 100 seeds of each cultivars of pigeonpea were recorded after drying the seed under sun, from the random sample taken from the whole plot. The average of three such samples were computed and correlated with pod borer complex.

2.5. Seed Density

Hundred seeds of pigeonpea were weighed and then transferred into a 100 ml measuring cylinder containing 50ml of tap water. The seeds were allowed to soak for 10 minutes for equibration and the volume of water displaced was recorded. The density was calculated thus:

$$\text{Density} = \text{mass/volume}$$

2.6. Trichome length and density

To measure trichome length and density, uniformly developed 10 pods were selected from each genotypes/cultivars from each replication. The wall of the plant material was cut into bits of 9 mm^2 (3 x 3) and number of trichomes present on the epidermis of the bits was counted under a binocular microscope. Similarly, trichome length was also measured with the aid of binocular microscope. Trichome length on pod was measured by gently pressing sticky transparent tape to the pod surface, trichomes adhered to the sticky surface of the tape were then fixed to a glass slide and trichome length was measured under a microscope with on ocular micrometer.

3. RESULTS AND DISCUSSION

3.1. LARVAL POPULATION OF POD BORERS AND SEED YIELD (POOLED):

3.1.1 *Helicoverpa armigera*:

Among the various genotypes/cultivars screened, lower larval population was observed in BP-17-02 (0.67) which was at par with BP-16-182 (0.96). The higher larval population was recorded in Vaishali (4.71) which was at par with GNP-2 (4.56) (Table-1).

3.1.2 *Maruca vitrata*:

Lower larval population of *Maruca* was observed in BP-17-02 (0.76) which was at par with ICPL-87119 (0.80), BP-16-228 (0.82), BP-16-178 (1.09), BP-16-166 (1.11),BP-16-182 (1.13) and BP-16-261 (1.13). Higher larval population was recorded in Vaishali (2.58) and GNP-2 (2.51) which remained statistically at par with each other (Table-1).

3.1.3 *Exelastis atomosa*:

Lower larval population of tur plume moth was observed in BP-17-02 (0.64), BP-16-228 (0.67), BP-16-166 (0.78) and ICPL-87119 (0.91) which remained at par with each other. The highest larval population was recorded in Vaishali (2.53) (Table-1)

3.1.4 *Melanagromyza obtusa*:

Pod damage due to pod fly was observed between 5.78 to 15.11 %. The lower damage was recorded in BP-16-261 (5.78), BP-17-02 (6.44) and BP-16-178 (7.22) and they remained at par. The higher damage was observed in AGT-2 (15.11) which was remained at par with Vaishali (14.33), GT-1 (13.22) and GNP-2 (12.89) (Table-1).

3.1.5 Seed yield (kg/ha):

The highest yield (kg/ha) was observed in BP-17-02 (1353) which remained significantly higher than rest of the treatments. The lower seed yield was recorded in AGT-2 (1021) which was at par with Vaishali (1024) (Table-1).

3.2. CATEGORIZATION OF PIGEONPEA GENOTYPES/CULTIVARS (POOLED):

3.2.1 *Helicoverpa armigera*:

BP-17-02 (0.67) was found highly resistant; BP-16-182 (0.96), BP-16-228 (1.24), BP-16-261 (1.49), ICPL-87119 (1.56), BP-16-183 (1.64) and BP-16-166 (1.71) found resistant; GT-1 (2.40) and BP-16-178 (2.42) found susceptible; AGT-2 (3.69), GNP-2 (4.56) and Vaishali (4.71) found highly susceptible against Helicoverpa armigera (Table-2).

3.2.2 *Maruca vitrata*:

BP-17-02 (0.76) was found highly resistant; ICPL-87119 (0.80), BP-16-228 (0.82), BP-16-178 (1.09), BP-16-166 (1.11), BP-16-261 (1.13) and BP-16-182 (1.13) found resistant; GT-1 (1.64), AGT-2 (1.69) and BP-16-183 (1.78) found susceptible; GNP-2 (2.51) and Vaishali (2.58) found highly susceptible against *M. vitrata* (Table-2).

3.2.3 *Exelastis atomosa*:

BP-17-02 (0.64), BP-16-228 (0.67) and BP-16-166 (0.78) was found highly resistant; ICPL 87119 (0.91) and BP-16-182 (1.16) found resistant; BP-16-178 (1.56), BP-16-261 (1.64), GT-1 (1.76), BP-16-183 (1.84), AGT-2 (1.89) and GNP-2 (1.96) found susceptible; Vaishali (2.53) found highly susceptible against *E. atomosa* (Table-2).

3.2.4 *Melanagromyza obtusa*:

BP-16-261(5.78) and BP-17-02 (6.44) found highly resistant; BP-16-178 (7.22), ICPL 87119 (8.78), BP-16-182 (8.89), BP-16-228 (9.11) and BP-16-183 (9.33) found resistant; BP-16-166 (10.67), GNP-2 (12.89) and GT-1 (13.22) found susceptible; Vaishali (14.33) and AGT-2 (15.11) found highly susceptible (Table-2).

Various researchers have screened the different pigeon pea genotypes for their susceptibility to pod borer complex. Kalariya *et al.,* [5] at Sardarkrushinagar, Gujarat reported less infestation of *H. armigera, E. atomosa* and *M. obtusa* on GAUT 85035 and BDN-2. Dhar and Singh [6] at Kanpur, Uttar Pradesh reported that ICPL 332 was found resistant to *H. armigera* in Andhra Pradesh. The highest damage due to *H. armigera* was observed in early maturing SKNP-0217. The damage *due* to *M. obtusa* was recorded lower in early maturing SKNP-0226 whereas; it was higher in medium late maturing genotype GAUT 2002-16 and variety BDN-2 [7]. Ghetiya [8] reported that the order of susceptibility against pod borer complex was found to be GT-1 > ICPL-87 > GT-100 > AVPP-1 > BDN-2 > Banas > GT-101 > GP-22 > GAUT-97-45 > GAUT-93-17 > GAUT-2002-16 > AAUT 2005-8 > GAUT-2001-10 > AAUT 2005-7 > GAUT-97-33 > ICPL- 87119. Bhadani [9] reported that based on larval population as well as pod and seed damage due to pod borers, genotypes/cultivars LRG 133-33, GT-103 and GT-100, BDN-2 and ICPL-87119 found tolerant; RVSA 16-02, AVPP-1, GNP-2 and Vaishali found susceptible whereas, rest of the genotypes/cultivars found mediocre. Thus, above reports for ICPL-87119 as a resistant variety and GNP-2 and Vaishali as susceptible varieties are in strongly accordance to results of present findings. The other genotypes/cultivars could not be compared as the tested genotypes/cultivars are from local area which could not be evaluated for their susceptibility elsewhere.

3.3. MORPHOLOGICAL CHARACTERS AND POD BORERS POPULATION (POOLED):

Genotypes/cultivars having short pod length (< 5.00cm), narrow pod breadth (<0.80cm), narrow seed breadth (< 5.50 mm), more seeds/pod (> 4.00), more seed weight (> 12g /100 seed), more seed density (> 1.30 g/ml), thick pod wall thickness (> 0.65 mm) and long trichome length (> 0.50 mm) recorded lower pod borers population (Table-3).

3.4. CORRELATION BETWEEN MORPHOLOGICAL CHARACTERS AND POD BORERS POPULATION (POOLED):

Among different morphological parameters, pod breadth (r=0.592) had a significant positive correlation with *H. armigera;* pod length (r=0.686) and pod breadth (r=0.648) had a significant positive correlation with *M. vitrata* population. Pod length (r=0.688) showed significant positive correlation and pod wall thickness (r=-0.596) showed significant negative correlation with *E. atomosa* population. Pod length exhibited (r=0.625) significant positive correlation with pod fly damage. The correlation of rest of the parameters were found non significant (Table-4).

The reports of positive association between pod borer infestation and pod length and pod breadth was reported by various workers; Nanda *et al,*[10] at Bhubneshwar, Orissa for pod length; Durairaj [11] at Vamban, Tamil Nadu for pod width, seed length and seed width; Chandrayadu *et al.,*[12] for pod size; Kamakshi and Srinivasan [13] at Tirupati for pod length; Ghetiya [8] at Anand, Guarat for pod length, width and seed weight; Jagtap *et al.*, [14] at Sardarkrushinagar, Gujarat and Bhadani [9] at Navsari, Gujarat for pod length and pod breadth. Thus, all these reports showed strongly confirmation to present findings.

Moudgal *et al.,*[15] at Hisar, Haryana found negative association between pod wall thickness and pod fly infestation in pigeon pea**.** Ghetiya [8] at Anand, Gujarat showed significant negative association between pod damage due to pod fly and pod wall thickness. Yadav [16] at Haryana reported negative association between pod borer damage and pod wall thickness. Jagtap *et al.*,[14] at Sardarkrushinagar, Gujarat reported that the thicker pod wall exhibited less preference for gram pod borer larvae. These reports are also in complete agreement with the present findings.

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Table-1 :- Response of various genotypes/cultivars against pod borers and pod fly infestation in pigeonpea (Pooled 2021-2023)

Sr.No.	Genotypes/Cultivars	*H. armigera* larva/pl	*M. vitrata* larva/pl	*E. atomosa* larva/pl	% Pod fly damage	Seed Yield (kg/ha)
1	BP-17-02	1.07*[a] (0.67)	1.10*[a] (0.76)	1.06*[a] (0.64)	14.59**[a] (6.44)	1353[a]

2	BP-16-228	1.31^{bc} (1.24)	1.13^{a} (0.82)	1.07^{a} (0.67)	17.40^{bc} (9.11)	1291^{b}
3	BP-16-178	1.70^{e} (2.42)	1.26^{a} (1.09)	1.43^{cd} (1.56)	15.51^{ab} (7.22)	1187^{de}
4	BP-16-182	1.20^{ab} (0.96)	1.26^{a} (1.13)	1.28^{bc} (1.16)	17.26^{bc} (8.89)	1192^{de}
5	BP-16-183	1.46^{d} (1.64)	1.51^{b} (1.78)	1.51^{d} (1.84)	17.59^{bc} (9.33)	1212^{cd}
6	BP-16-166	1.48^{d} (1.71)	1.26^{a} (1.11)	1.11^{ab} (0.78)	18.89^{cd} (10.67)	1217^{cd}
7	BP-16-261	1.39^{cd} (1.49)	1.26^{a} (1.13)	1.45^{cd} (1.64)	13.53^{a} (5.78)	1187^{de}
8	Vaishali	2.27^{g} (4.71)	1.75^{c} (2.58)	1.74^{e} (2.53)	22.19^{e} (14.33)	1024^{f}
9	AGT-2	2.02^{f} (3.69)	1.47^{b} (1.69)	1.54^{d} (1.89)	22.75^{e} (15.11)	1021^{f}
10	GT-1	1.69^{e} (2.40)	1.46^{b} (1.64)	1.49^{d} (1.76)	20.98^{de} (13.22)	1255^{bc}
11	ICPL-87119 (C)	1.42^{cd} (1.56)	1.11^{a} (0.80)	1.17^{ab} (0.91)	17.11^{bc} (8.78)	1278^{b}
12	GNP-2 (C)	2.23^{g} (4.56)	1.73^{c} (2.51)	1.53^{d} (1.96)	20.93^{de} (12.89)	1155^{e}
	S.Em. ± (T)	0.05	0.06	0.06	0.88	17.11
	C.D. at 5% (T)	0.14	0.17	0.17	2.49	50.19
	S.Em. ± (Y x T)	0.09	0.10	0.10	1.52	60.10
	C.D. at 5% (Y x T)	NS	NS	NS	NS	NS
	CV%	9.90	13.50	13.62	14.51	8.69

Note: * $\sqrt{X+0.5}$ transformed values, ** arc sine transformed values
Figures in parentheses are original mean values.
Treatment means with letter(s) in common are not significantly different at 5% level of significance

Table-2: Categorization of pigeonpea genotypes/cultivars for their susceptibility to pod borers larval population (Pooled 2021-23)

Category of susceptibility	Scale	Cultivars / Genotypes
1. *Helicoverpa armigera*	$\bar{x}$ **= 2.25**	**S.D. = 1.36**

Highly Resistant (HR)	Xi < 0.89	BP-17-02 (0.67)
Resistant (R)	Xi > 0.89 < 2.25	BP-16-182 (0.96), BP-16-228 (1.24), BP-16-261 (1.49), ICPL-87119 (1.56), BP-16-183 (1.64), BP-16-166 (1.71)
Susceptible (S)	Xi > 2.25 < 3.62	GT-1 (2.40), BP-16-178 (2.42)
Highly Susceptible (HS)	Xi > 3.62 < 4.98	AGT-2 (3.69), GNP-2 (4.56), Vaishali (4.71)
2. *Maruca vitrata*	$\bar{x}$ **= 1.42**	**S.D. = 0.63**
Highly Resistant (HR)	Xi < 0.79	BP-17-02 (0.76)
Resistant (R)	Xi > 0.79 < 1.42	ICPL-87119 (0.80), BP-16-228 (0.82), BP-16-178 (1.09), BP-16-166 (1.11), BP-16-261 (1.13), BP-16-182 (1.13)
Susceptible (S)	Xi > 1.42< 2.05	GT-1 (1.64), AGT-2 (1.69), BP-16-183 (1.78)
Highly Susceptible (HS)	Xi > 2.05 < 2.68	GNP-2 (2.51), Vaishali (2.58)
3. *Exelastis atomosa*	$\bar{x}$ **= 1.44**	**S.D. = 0.60**
Highly Resistant (HR)	Xi < 0.84	BP-17-02 (0.64), BP-16-228 (0.67), BP-16-166 (0.78)
Resistant (R)	Xi > 0.84 < 1.44	ICPL 87119 (0.91), BP-16-182 (1.16)
Susceptible (S)	Xi > 1.44 < 2.05	BP-16-178 (1.56), BP-16-261 (1.64), GT-1 (1.76), BP-16-183 (1.84), AGT-2 (1.89), GNP-2 (1.96)
Highly Susceptible (HS)	Xi > 2.05 < 2.65	Vaishali (2.53)
4. Pod fly	$\bar{x}$ **= 10.15**	**S.D. = 3.10**
Highly Resistant (HR)	Xi < 7.05	BP-16-261(5.78), BP-17-02 (6.44)
Resistant (R)	Xi > 7.05 < 10.15	BP-16-178 (7.22), ICPL 87119 (8.78), BP-16-182 (8.89), BP-16-228 (9.11), BP-16-183 (9.33)
Susceptible (S)	Xi > 10.15 < 13.25	BP-16-166 (10.67), GNP-2 (12.89), GT-1 (13.22)
Highly Susceptible (HS)	Xi > 13.25 < 16.35	Vaishali (14.33), AGT-2 (15.11)

Table-3: Influence of different morphological characters on larval population of pod borers in various pigeonpea genotypes/cultivars (Pooled 2021-23)

Plant character	Range	Category	Larval population (larva/plant)		
			H. armigera	***M. vitrata***	***E. atomosa***
Pod length (cm)	> 5.00	Long (5)	3.40±1.35	2.04±0.46	2.00±0.31
	< 5.00	Short (7)	1.44±0.56	0.98±0.17	1.05±0.41
Pod breadth (cm)	> 0.80	Broad (4)	3.31±1.57	1.88±0.84	1.79±0.67
	< 0.80	Narrow (8)	1.73±0.95	1.19±0.37	1.27±0.53
Seed length (mm)	> 6.00	Long (6)	2.08±1.34	1.49±0.63	1.44±0.57
	< 6.00	Short (6)	2.43±1.49	1.35±0.68	1.45±0.69
Seed breadth (mm)	> 5.50	Broad (5)	3.01±1.60	1.79±0.72	1.79±0.51
	< 5.50	Narrow (7)	1.71±0.94	1.16±0.42	1.20±0.57
No. of seeds / pod	> 4.00	More (7)	1.64±0.62	1.05±0.31	1.14±0.49
	< 4.00	Less (5)	3.11±1.72	1.94±0.61	1.88±0.49
Seed weight (g /100 seed)	> 12.00	More (6)	2.11±0.95	1.30±0.28	1.47±0.42
	< 12.00	Less (6)	2.40±1.77	1.54±0.87	1.43±0.79
Seed density	> 1.30	More (5)	1.91±1.04	1.30±0.42	1.32±0.52

(g/ml)	< 1.30	Less (7)	2.50±1.59	1.50±0.77	1.54±0.68
Pod wall thickness(mm)	> 0.65	Thick (7)	1.64±0.62	1.05±0.31	1.14±0.49
	< 0.65	Thin (5)	3.11±1.72	1.94±0.61	1.88±0.49
Trichome length (mm)	> 0.50	Long (7)	2.08±1.46	1.40±0.63	1.43±0.53
	< 0.50	Short (5)	2.50±1.33	1.45±0.70	1.46±0.76
Trichome density (trichome/9mm^2)	> 40	More (4)	2.76±1.62	1.46±0.82	1.36±0.66
	< 40	Less (8)	2.00±1.25	1.40±0.58	1.49±0.61
Note : Figures in parentheses are numbers of genotypes/cultivars					

Table- 4: Correlation between morphological characters and pod borers larval population in various pigeonpea genotypes/cultivars (Pooled 2021-23)

Plant characters	Larva/plant			Pod fly damage (%)
	H. armigera	***M. vitrata***	***E. atomosa***	
Pod length (cm)	0.531	0.686*	0.688*	0.625*
Pod breadth (cm)	0.592*	0.648*	0.561	0.492
Seed length (mm)	0.060	0.191	0.117	0.145
Seed breadth (mm)	0.029	0.083	0.129	0.086
No. of seeds / pod	-0.411	-0.499	-0.429	-0.196
Seed weight (g /100 seed)	0.191	0.099	0.294	0.258
Seed density (g/ml)	0.068	0.024	0.040	0.201
Pod wall thickness (mm)	-0.325	-0.558	-0.596*	-0.332
Trichome length (mm)	-0.261	-0.217	-0.336	-0.280
Trichome density (trichome/9mm^2)	0.290	0.180	-0.003	0.190
* Significant at 5% level of significance				

4. CONCLUSION

BP-17-02 was found highly resistant and BP-16-182, BP-16-228, BP-16-261, ICPL-87119 and BP-16-166 were found resistant whereas, GNP-2 and Vaishali were found highly susceptible against pod borers. Genotypes/cultivars *viz.,* BP-16-178, ICPL 87119, BP-16-182, BP-16-228 and BP-16-183 were found resistant to pod fly. Genotypes/cultivars having short pod length, narrow pod breadth, narrow seed breadth, more seeds/pod, more seed weight, more seed density, thick pod wall thickness and long trichome length recorded lower pod borers population. Pod length had a significant positive correlation with *Maruca vitrata, Exelastis atomosa* and *Melanagromyza obtusa*. Significant positive association was found between pod breadth and larval population of *Helicoverpa armigera* and *Maruca vitrata*. Significant negative correlation was found between *Exelastis atomosa* and pod wall thickness

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