Morpho Physico-Chemical Components of Resistance to Pod Borer, *Helicoverpa armigera* (Hübner) in Pigeonpea [*Cajanus cajan* (L.) Millspaugh]

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Abstract

The experiments were conducted at CCS HAU, Hisar (Haryana) to study the morpho physico-chemical components of resistance to pod borer, *Helicoverpa armigera* in pigeonpea with different sowing dates. In different four sowing dates, the minimum pod infestation (1.70%) was recorded in (D_4) 3rd week of July sown crop, whereas, it was observed maximum (4.54%) in (D_2) 1st week of July sown crop. In different pigeonpea varieties, the minimum mean pod infestation (2.45%) was recorded in AL-201, whereas, the maximum mean pod infestation (3.72%) was recorded in Pusa-992. The glandular (type A) and non-glandular (type B) trichomes on pods of top and middle canopy of the plant and pod wall thickness were associated with resistance to *H. armigera*, whereas, the non-glandular lengthy (type C) trichomes and pod length were associated with susceptibility to this insect. The expression of resistance to *H. armigera* was also associated with the high amount of fat, phenol and tannin content. Crude protein and total soluble sugar content were responsible for higher pod infestation.

Key words: *H. armigera*, Morpho physico-chemical components, Pigeonpea, Resistance.

Introduction

Pigeonpea (*Cajanus cajan* L) is a tropical pulse legume mainly grown in India, ranks second in area and production. More than 300 species of insects feed on pigeonpea of which pod borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is the most devastating pest worldwide (Prasad and Singh, 2004; Sharma, 2001). It attacks the reproductive structures of plant and causes the maximum yield losses (Rangaiah and Sehgal, 1984). In the semi-arid tropics, the losses due to this pest in pigeonpea have been estimated up to US$ 400 million (ICRISAT 2007). Excessive and indiscriminate use of chemical insecticides not only causes the economical burden on farmers but also produces the harmful side effects on the environment as well as human beings. Since *H. armigera* has developed high levels of resistance to insecticides, it has become difficult to manage this pest on pigeonpea and several other crops with conventional insecticides (Kranthi *et al*., 2002; Sharma, 2005). Therefore, there is need to develop alternative methods to minimize the extent of losses. Development of insect-resistant cultivars has a considerable potential for use in integrated pest management, particularly under subsistence farming conditions in developing countries (Sharma, 2005). However, screening of more than 14,000 accessions of pigeonpea for resistance to *H. armigera* has revealed low to moderate levels of resistance in the cultivated genotypes (Reed and Lateef, 1990). However, a few accessions of the wild relatives of pigeonpea have shown high levels of resistance to *H. armigera* (Sharma *et al*., 2001; Green *et al*., 2006).

Various morphological traits like trichome length and its density on pods, pod length and pod wall thickness have been reported to be associated resistance to *H. armigera* (Shanower *et al*., 1997; Haldar *et al*., 2006). Besides the morphological traits, chemical compounds in trichome exudates and on pod wall surface also influence the host plant selection and colonization by *H. armigera* (Hartlieb and Rembold 1996; Green *et al*., 2002, 2003). In addition, pigeonpea also contains anti-nutritional factors such as proteinase inhibitors, oligosaccharides, phenols, tannins and phytic acid (Singh, 1988), which may influence the host plant suitability to *H. armigera*. Therefore, the present study was conducted to ascertain the role of morphological and biochemical constituents in relation to expression of resistance to pod borer *H. armigera* in pigeonpea.

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Materials and Methods

The experiments were conducted during *Kharif* season 2013 and 2014 to study the morpho physico-chemical components of resistance in pigeonpea plants against *H. armigera*. Six short duration pigeonpea varieties *viz*., Manak, Paras, Pusa-992, AL-201, PAU-881 and H03-41 were sown at four different dates i.e. D_1 (3rd week of June), D_2 (1st week of July), D_3 (2nd week of July) and D_4 (3rd week of July). The experiment was laid out at Pulses Farm, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar in plot size of 4 rows of 4 m length (1.8 m × 4 m) with spacing of 45 cm × 15 cm keeping three replications in randomized complete block design. For observing the *H. armigera* infestation, 150 pods from each plot per replication were plucked at the time of harvesting and brought to the laboratory and examined carefully. The circular holes on the pods considered as the infestation of *H. armigera* and the per cent pod damage was worked out.

The morphological and biochemical components *viz*., trichome density of pods (top, middle and bottom canopy), pod length, pod wall thickness, seed length and seed width, number of seeds per pod and 50% flowering and biochemical components *viz*., crude protein, moisture content, total soluble sugars, fats, total phenols, tannins and chlorophyll content of seed as well as pod wall were studied using standard procedures. To study the morphological traits, a total of 25 freshly 25 days old pods of pigeonpea were randomly plucked and collected from each genotype per replication. Trichome density of pods was determined by Sass (1964) method. Pod wall thickness, pod length, seed length and width was measured by using Vernier calipers and expressed in mm. The number of seeds per pod from each genotype was counted on the basis of number of locules unfilled as well as filled up with the seeds. The 50 per cent flowering was determined by visual observation of each plot of each replication of all the sowing dates.

To study the biochemical constituents from seeds as well as pod wall, the sufficient number of pods of 15 days old were plucked and collected from each replication of each plot. The pods were kept in marked brown paper bags having wax coated inner side. The samples were brought to the laboratory, kept in airtight plastic container and stored at 4°C in deep freeze during the study period. Pod wall and green seeds of these pods were taken for further biochemical analysis. The one set of pods were oven dried at 60°C for 2-3 days. After drying, the test samples were grind and grinded samples of seeds as well as pod wall were then kept in a paper envelop in oven at 50°C for one day to ensure complete drying of the samples. The completely dried samples were used for the estimation of biochemical constituents.

The crude protein content was estimated by the method described by AOAC (1985). Moisture content was determined by Mehta and Lodha (1979) method. For the estimation of total soluble sugar, the method described by (Dubios *et al*., 1956) was followed. Fat estimation was worked out by using the method narrated by AOAC (1975). For the estimation of total phenol, method narrated by Bray and Thorpe (1954) was followed. Tannin content was estimated by following the method of AOAC (1965). Chlorophyll content was estimated by Hiscox and Israelstam (1979) method. Data was subjected to analysis of variance using SPSS statistics, 19 version statistical package as suggested by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Helicoverpa armigera infestation

The data on impact of sowing dates and varieties on per cent pod damage were significant during both the years 2013 and 2014 and presented in Table 1. The results on pod infestation by *H. armigera* during 2013 revealed that in different sowing dates, the maximum mean pod infestation (4.22%) was recorded in D_2 (1st week of July) sown crop and it was statistically at par with D_1 (3rd week of June) sown crop (3.66%), whereas, infestation was recorded minimum (1.91%) in D_4 (3rd week of July) sown crop. In D_3 (2nd week of July) sown crop the pod infestation was 3.17 per cent. In different pigeonpea varieties the minimum mean pod infestation (2.38%) by *H. armigera* was recorded in variety AL-201 and it was statistically at par with H03-41 (2.65%). The maximum mean pod infestation (3.85%) was recorded in variety Pusa-992 which was statistically at par with Manak

Table 1: Pod infestation by pod borer, *Helicoverpa armigera* in different pigeonpea varieties during 2013.

	Sowing	Variety						Mean
		Paras	Manak	AL-201	Pusa-992	PAU-881	H03-41	
	D_1	4.15(11.75)	3.76(11.18)	2.46(9.02)	4.66(12.46)	3.45(10.70)	3.47(10.73)	3.66(10.97)
H. armigera	D_2	5.07(12.38)	3.27(10.19)	3.07(9.86)	4.42(12.13)	5.25(13.08)	4.23(11.67)	4.22(11.55)
	D_3	1.34(6.61)	5.72(13.57)	2.50(9.06)	4.09(10.99)	3.59(10.51)	1.78(7.63)	3.17(9.73)
	D_4	1.61(7.29)	2.56(9.20)	1.50(7.04)	2.22(8.37)	2.42(8.82)	1.14(6.13)	1.91(7.81)
Mean		3.04(9.57)	3.83(10.99)	2.38(8.75)	3.85(11.04)	3.68(10.78)	2.65(9.04)	-
SE(m)	Sowing							0.52
	Varieties							0.64
	Sowing × Varieties							1.27
CD(P = 0.05)	Sowing							1.48
	Varieties							1.81
	Sowing × Varieties							NS

D_1= First sowing; D_2= Second sowing; D_3= Third sowing; D_4= Fourth sowing.

(3.83%), PAU-881 (3.68%) and Paras (3.04%). The interaction effect of varieties and sowing dates was non-significant.

The data on pod infestation during 2014 are presented in Table 2 and a significant difference was observed in different sowing dates and varieties. Pod infestation in different sowing dates revealed that the maximum mean pod infestation (4.86%) was recorded in D_2 (1st week of July) sown crop, whereas, it was minimum (1.49%) in D_4 (3rd week of July) sown crop. In D_1 (3rd week of June) sown crop and D_3 (2nd week of July) sown crop the pod infestation was 3.48 and 3.20 per cent, respectively. In varieties the pod infestation by *H*. *armigera* was recorded minimum (2.51%) in variety AL-201, which was statistically at par with H03-41 and Paras with the pod infestation of 2.90 and 3.42 per cent, respectively. Maximum pod infestation (3.60%) was recorded in variety Pusa-992 and it was statistically at par with Manak and PAU-881 with the per cent pod infestation 3.59 and 3.51 per cent, respectively. The interaction effect of sowing dates and varieties was significant.

The pooled mean of pod infestation for two years 2013 and 2014 are presented in Table 3. Minimum mean pod infestation (1.70%) was recorded in D_4 (3rd week of June) sown crop, whereas, it was maximum (4.54%) in D_2 (1st week of July) sown crop. In D_1 (3rd week of June) sown crop and D_3 (2nd week of July) sown crop the pod infestation was 3.56 and 3.18 per cent, respectively. The data pooled over years on pod infestation revealed that the variety AL-201 registered lower pod infestation of 2.45 per cent and it was statistically at par with H03-41 and Paras with the per cent pod infestation of 2.77 and Paras 3.24 per cent. Among the different pigeonpea varieties, Pusa-992 recorded the maximum mean pod infestation (3.72%) which was statistically at par with variety Manak and PAU-881 with the pooled mean pod infestation of 3.71 and 3.59 per cent, respectively. The interaction effect of sowing dates and varieties of pooled over years was observed significant and the pod infestation was influenced by the sowing dates and varieties.

The present studies corroborate with the findings of Reddy *et al*. (2001), who reported that the early sowing (mid-June) of the pigeonpea crop resulted in lower incidence of *H*. *armigera*. The results are not in confirmity with the findings of Prasad *et al*. (1986), who found minimum pod damage due to *H*. *armigera* in the late (10th July) sown pigeonpea crop. However, Kushwaha and Malik (1987) found minimum pod damage by pod borer, *H*. *armigera* in early sown crop (April sown), while it was maximum in late sown pigeonpea crop. Whereas, Pol *et al*. (1992) observed non-significant effect of sowing dates on the infestation of pod borers on pigeonpea.

Correlation of morpho physico-chemical traits of seeds and pod wall with expression of resistance to *Helicoverpa armigera*

The significant difference was observed in various morphological and biochemical factors of seeds as well as pod wall of various pigeonpea varieties (Table 4 and Table 5**)**.

Trichome density of pods of top canopy of the plant

The trichome density of top, middle and bottom canopy of the resistant varieties were significantly higher than the susceptible varieties. During the year 2013, the significant and negative association (r = -0.835*, r = -0.733*, r = -0.778*) and (r = -0.825*, r = -0.740*, r = -0.732*) of *H. armigera* pod infestation was observed with glandular (Type A) and non-glandular (Type B) pod trichomes during D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crop (Table 4). Whereas, with the non-glandular lengthy (Type C) pod trichomes, the pod infestation was observed significantly positive (r = 0.790*) in D_2 (1st week of July) sown crop. During 2014 the pod infestation was significantly negatively correlated (r = -0.821* and r = -0.833*) non-glandular (Type B) pod trichomes during D_1 (3rd week of June) and D_4 (3rd week of July) sown crop. Similarly, with the non-glandular lengthy (Type C) pod trichomes, the significant and positive correlation (r = 0.794*) was observed in D_2 (1st week of July) sown crop. The results of pooled over years indicated significant negative correlation (r = -0.730*, r = -0.768*, r = -0.729*) and (r = -0.864*, r = -0.734*, r = -0.776*) between pod

Table 2: Pod infestation by pod borer, *Helicoverpa armigera* in different pigeonpea varieties during 2014.

	Sowing	Variety						Mean
		Paras	Manak	AL-201	Pusa-992	PAU-881	H03-41	
	D_1	3.69(11.07)	3.09(10.02)	2.78(9.59)	4.02(11.56)	3.47(10.73)	3.83(11.28)	3.48(10.71)
H. armigera	D_2	6.21(14.41)	3.94(11.41)	3.74(11.04)	4.48(12.20)	5.90(14.01)	4.88(12.69)	4.86(12.62)
	D_3	2.66(9.37)	5.30(13.08)	2.34(8.73)	4.05(11.58)	2.95(9.65)	1.89(7.71)	3.20(10.20)
	D_4	1.17(6.10)	2.09(8.22)	1.16(6.17)	1.82(7.64)	1.70(7.39)	1.00(4.64)	1.49(6.69)
Mean		3.42(10.24)	3.59(10.68)	2.51(8.88)	3.60(10.74)	3.51(10.44)	2.90(9.08)	-
SE(m)	Sowing							0.40
	Varieties							0.48
	Sowing × Varieties							0.95
CD(P = 0.05)	Sowing							1.11
	Varieties							1.36
	Sowing × Varieties							2.71

D_1= First sowing; D_2= Second sowing; D_3= Third sowing; D_4= Fourth sowing.

Table 3: Pod infestation by pod borer, *Helicoverpa armigera* in different pigeonpea varieties (Pooled).

	Sowing	Variety						Mean
		Paras	Manak	AL-201	Pusa-992	PAU-881	H03-41	
H. armigera	D_1	3.92(11.41)	3.40(10.62)	2.62(9.31)	4.34(12.02)	3.46(10.71)	3.65(11.00)	3.56(10.85)
	D_2	5.64(13.71)	3.60(10.87)	3.41(10.59)	4.45(12.17)	5.58(13.63)	4.56(12.25)	4.54(12.20)
	D_3	2.00(8.12)	5.51(13.33)	2.42(8.90)	4.07(11.41)	3.27(10.10)	1.84(7.70)	3.18(9.93)
	D_4	1.39(6.75)	2.32(8.75)	1.33(6.63)	2.02(8.02)	2.06(8.24)	1.07(5.73)	1.70(7.35)
Mean		3.24(10.00)	3.71(10.89)	2.45(8.86)	3.72(10.90)	3.59(10.67)	2.77(9.17)	-
SE(m)	Sowing							0.34
	Varieties							0.42
	Sowing × Varieties							0.83
CD(P = 0.05)	Sowing							0.97
	Varieties							1.19
	Sowing × Varieties							2.37

D_1= First sowing; D_2= Second sowing; D_3= Third sowing; D_4= Fourth sowing.

infestation and glandular (Type A) and non-glandular (Type B) pod trichomes in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crop. Similarly, the correlation between non-glandular lengthy (Type C) pod trichomes and pod infestation was significantly positive in D_2 (1st week of July) sown crop.

Trichome density of pods of middle canopy of the plant

During the year 2013, the significant and negative correlation (r = -0.828*, r = -0.751*) was observed between glandular (Type A) pod trichomes and pod infestation in D_1 (3rd week of June) and D_2 (1st week of July) sown crops (Table 4). With non-glandular (Type B) pod trichomes the correlation was also significant and negative (r = -0.812*, r = -0.705*) in D_1 (3rd week of June) and D_4 (3rd week of July) sown crops. While, the highly significant and positive correlation (r = 0.955**, r = 0.732*, r = 0.862*) was observed between non-glandular (Type C) pod trichomes and pod infestation in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crop. During 2014 the correlation was significant negative (r = -0.760*) between pod infestation and glandular (Type A) pod trichomes in D_2 (1st week of July) sown crop. With non-glandular (Type B) pod trichomes in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop, the correlation was significant negative (r = -0.838*, r = -0.776*) with pod infestation. Whereas, with the non-glandular lengthy (Type C) pod trichomes the correlation was significant positive (r = 0.859*, r = 0.775*) in D_1 (3rd week of June) and D_4 (3rd week of July) sown crop. The pooled results of both the years showed significant negative correlation (r = -0.751*, r = -0.766*) with the glandular (Type A) pod trichomes in D_1 (3rd week of June) and D_2 (1st week of July) sown crop and (r = -0.729*, r = -0.730*, r = -0.742*) with non-glandular (Type B) pod trichomes in D_1 (3rd week of June), D_3 (2nd week of July) and D_4 (3rd week of July) sown crop, respectively. Whereas, the correlation was significant positive (r = 0.964** and r = 0.832*) between pod infestation and non-glandular lengthy (Type C) pod trichomes in D_1 (3rd week of June) and D_4 (3rd week of July) sown crop.

Trichome density of pods of lower canopy of the plant

The significant and negative correlation (r = -0.707* and r = -0.787*) of pod infestation was observed with non-glandular lengthy pod trichomes (Type C) during the year 2013 in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop (Table 4). During the year 2014 the pod infestation was significantly and negatively correlated (r = -0.756*) with glandular (Type A) pod trichomes in D_2 (1st week of July) sown crop. Similarly, with non-glandular (Type C) pod trichomes the correlation was significant negative (r = -0.869* and r = -0.710*) in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop. In pooled results the similar correlation was observed as significantly negative correlation (r = -0.725*) with glandular (Type A) pod trichomes in D_2 (1st week of July) and (r = -0.794* and r = -0.760*) with non-glandular (Type C) pod trichomes in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop, respectively.

Jagtap *et al*. (2014) reported more or less similar results, according to them the genotypes of pigeonpea having non-glandular pod trichomes were least favored by the larvae of *H. armigera* than genotypes having glandular pod trichomes. Whereas, contrasting results were reported by Sharma *et al*. (2009), glandular trichomes (type A) on the calyxes and pods were associated with the susceptibility to *H. armigera*, while the non-glandular trichomes (trichome type C and D) were associated with resistance to this insect.

Pod length

During the year 2013 a significant and positive correlation (r = 0.752* and r = 0.888**) was observed between the pod infestation and pod length during D_1 (3rd week of June) and D_2 (1st week of July) sown crop (Table 4). The similar results were also observed during the year 2014, a significant and positive correlation (r = 0.725* and r = 0.746*) was observed between pod length and the pod infestation by the pod borer

Table 4: Correlation coefficient (r) between morphological characters and pod borer, *H. armigera* incidence in pigeonpea.

	Morphological traits													
	2013													
	Trichomes (/mm^2)									Pod length (mm)	Pod wall thickness (mm)	Seed length (mm)	Seed width (mm)	No. of seeds / pod
	Top canopy			Middle canopy			Lower canopy							
	A	B	C	A	B	C	A	B	C					
D_1	-0.835*	-0.825*	0.571	-0.828*	-0.812*	0.955**	-0.014	-0.135	-0.190	0.752*	-0.910**	0.589	0.826*	0.462
D_2	-0.733*	-0.740*	0.790*	-0.751*	-0.039	0.732*	-0.670	-0.120	0.124	0.888**	-0.739*	0.716*	0.536	0.743*
D_3	-0.500	-0.659	0.085	0.403	-0.621	0.396	-0.030	-0.523	-0.707*	0.111	-0.479	0.130	0.101	0.220
D_4	-0.778*	-0.732*	0.158	0.354	-0.705*	0.862*	-0.416	-0.552	-0.787*	0.119	-0.804*	0.041	0.372	0.703*
* Significant at P = 0.05; ** Significant at P = 0.01.														
	2014													
D_1	-0.478	-0.821*	0.683	-0.554	-0.513	0.859*	0.340	0.352	0.335	0.725*	-0.801*	0.891**	0.806*	0.597
D_2	-0.593	-0.673	0.794*	-0.760*	0.122	0.539	-0.756*	-0.080	0.130	0.746*	-0.720*	0.550	0.597	0.704*
D_3	-0.547	-0.634	0.204	0.408	-0.838*	0.633	-0.159	-0.186	-0.869*	0.272	-0.756*	0.212	0.381	0.315
D_4	-0.638	-0.833*	0.099	0.493	-0.776*	0.775*	-0.223	-0.399	-0.710*	0.080	-0.778*	-0.022	0.172	0.589
* Significant at P = 0.05; ** Significant at P = 0.01.														
	Pooled (2013 and 2014)													
D_1	-0.730*	-0.864*	0.646	-0.751*	-0.729*	0.964**	0.129	0.059	0.019	0.774*	-0.909**	0.746*	0.860*	0.535
D_2	-0.768*	-0.734*	0.803*	-0.766*	0.048	0.639	-0.725*	-0.099	0.129	0.825*	-0.739*	0.638	0.577	0.780*
D_3	-0.531	-0.662	0.139	0.414	-0.730*	0.510	-0.088	-0.384	-0.794*	0.185	-0.612	0.169	0.228	0.267
D_4	-0.729*	-0.776*	0.133	0.416	-0.742*	0.832*	-0.337	-0.492	-0.760*	0.103	-0.801*	0.014	0.289	0.759*

* Significant at P = 0.05; ** Significant at P = 0.01.

D_1= First sowing; D_2= Second sowing; D_3= Third sowing; D_4= Fourth sowing.

Table 5: Correlation coefficient (r) between biochemical constituents and pod borer, *H. armigera* incidence in pigeonpea.

	Biochemical constituents													
	Chlorophyll (mg g^{-1})		Moisture (%)		Crude protein(%)		Fat (%)		Phenol (mg g^{-1})		Total soluble sugar (%)		Tannin (µg g^{-1})	
	Seed	Podwall	Seed	Pod wall	Seed	Pod wall	Seed	Pod wall	Seed	Pod wall	Seed	Pod wall	Seed	Pod wall
2013														
D_1	0.363	0.776*	0.492	0.623	0.497	0.763*	-0.823*	-0.241	-0.853*	-0.788*	0.818*	0.601	-0.647	-0.075
D_2	0.427	0.488	0.762*	0.035	0.510	0.202	-0.733*	-0.735*	-0.723*	-0.743*	0.735*	0.902**	-0.828*	-0.739*
D_3	0.581	0.054	-0.023	0.500	0.735*	0.422	0.555	-0.511	-0.511	0.326	0.219	0.489	0.206	-0.637
D_4	0.801*	0.211	0.003	0.267	0.721*	-0.234	-0.066	-0.148	0.001	0.160	0.338	0.810*	0.611	0.221
* Significant at P = 0.05; ** Significant at P = 0.01.														
2014														
D_1	0.620	0.323	0.203	0.104	0.201	0.620	-0.860*	0.225	-0.850*	-0.376	0.540	0.763*	-0.911**	-0.100
D_2	0.337	0.430	0.840*	0.192	0.736*	0.013	-0.605	-0.734*	-0.519	-0.637	0.823*	0.872*	-0.775*	-0.515
D_3	0.721*	0.423	0.298	0.690	0.869*	0.572	0.587	-0.569	-0.569	0.389	0.279	0.587	0.069	-0.490
D_4	0.675	0.192	0.047	0.363	0.683	-0.270	-0.096	-0.062	0.062	0.201	0.369	0.812*	-0.748*	0.309
* Significant at P = 0.05; ** Significant at P = 0.01.														
Pooled (2013 and 2014)														
D_1	0.485	0.626	0.391	0.435	0.304	0.740*	-0.884**	-0.060	-0.900**	-0.656	0.738*	0.698	-0.792*	-0.086
D_2	0.384	0.465	0.815*	0.119	0.639	0.104	-0.675	-0.743*	-0.625	-0.697	0.793*	0.898**	-0.812*	-0.630
D_3	0.655	0.219	0.119	0.595	0.810*	0.497	0.580	-0.547	-0.547	0.361	0.250	0.543	0.149	-0.585
D_4	0.753*	0.206	0.023	0.313	0.711*	-0.253	-0.080	-0.113	0.028	0.181	0.356	0.819*	0.676	0.262

* Significant at P = 0.05; ** Significant at P = 0.01.

D_1= First sowing; D_2= Second sowing; D_3= Third sowing; D_4= Fourth sowing.

in D_1 (3rd week of June) and D_2 (1st week of July) sown crop. The results of pooled over years revealed that the correlation between the pod length and the pod infestation by the pod borer was significant and positive (r = 0.774* and r = 0.825*) in D_1 (3rd week of June) and D_2 (1st week of July) sown crop, respectively. The results are in line with the findings of Jagtap *et al*. (2014), according to them the genotypes having shorter pod length were preferred lesser by the larvae than the pigeonpea genotypes having longer pods. The findings postulated by Thakur *et al*. (1989) were also in agreement, who reported positive relationship between pod length and pod borer infestation.

Pod wall thickness

During 2013 the pod infestation was significant and negatively correlated (r = -0.910**, r = -0.739*, r = -0.804*) in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crop, respectively (Table 4). During the year 2014 the correlation was significant and negative (r = -0.801*, r = -0.720*, r = -0.756*, r = -0.778*) in all the sowing dates. In pooled results the correlation was significant and negative (r = -0.909**, r = -0.739*, r = -0.801*) in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crop, respectively. The results were in confirmity with the findings of Jagtap *et al*. (2014), according to them the thicker pod wall exhibited lesser preference for larvae than the genotypes evincing thinner pod wall and it can be regarded as a non-preferential attributes for *H. armigera*. The present findings are also in confirmity with the findings of Dodia and Patel (1994).

Seed length

During the year 2013 the seed length was significant and positively correlated (r = 0.716*) in D_2 (1st week of July) sown crop (Table 4). During 2014 the correlation was highly significant and positive (r = 0.891**) between seed length and pod infestation in D_1 (3rd week of June) sown crop. The pooled results was also showed significant and positive correlation (r = 0.746*) between seed length and pod infestation in D_1 (3rd week of June) sown crop. The results were in accordance with Sahoo and Senapati (2000), who reported that the seed length had a positive effect on the incidence of *H. armigera*. With respect to *H. armigera*, the positive correlation of seed size was observed in the present study corroborate with the findings of Wightman *et al*. (1994) and Dodia and Patel (1994).

Seed width

The correlation was significant and positive (r = 0.826*, r = 0.806*, r = 0.860*) between seed width and pod infestation during both the years (2013 and 2014) and pooled results in D_1 (3rd week of June) sown crop (Table 4). The results were in confirmity with the findings of Sahoo and Senapati (2000) and their study revealed that the positive correlation between seed width and incidence of *H. armigera* in pigeonpea crop.

Number of seeds per pod

During the year 2013 the pod infestation was significant and positively correlated (r = 0.743*, r = 0.703*) with number of seeds per pod in D_2 (1st week of July) and D_4 (3rd week of July) sown crop (Table 4). During 2014 the correlation between pod infestation and number of seeds per pod was also observed significant and positive (r = 0.704*) in D_{2}. (1st week of July) sown crop. Pooled results of the two years (2013 and 2014) showed significant and positive association (r = 0.780*, r = 0.759*) between pod infestation and number of seeds per pod in D_2 (1st week of July) and D_4 (3rd week of July) sown crops.

Chlorophyll content

During the year 2013 the correlation was significant and positive (r = 0.776*, r = 0.801*) between chlorophyll content of pod wall as well as seed during D_1 (3rd week of June) and D_4 (3rd week of July) sown crop (Table 5). In the year 2014 the correlation was significant and positive (r = 0.721*) between chlorophyll content of seed in D_3 (2nd week of July) sown crop. The pooled results shows significant and positive correlation (r = 0.753*) between chlorophyll content of seed in D_4 (3rd week of July) sown crop. The results were in agreement with the findings of Tripathi and Purohit (1983) and Dodia (1992) who reported maximum damage of pod borer on green colour pods in pigeonpea, while the least damage was observed in pods with brown streaks. Contrasting results were postulated by Jagtap *et al*. (2014), according to them genotypes having green and green with brown streaks colour pod evinced lesser preference for larval feeding than the genotypes having green pods with purple streaks. Dua *et al*. (2005) also gave confirmation support of brown seed and green pod having streaks associated with resistance to *H. armigera* in pigeonpea.

Moisture

The pod infestation was significant and positively correlated (r = 0.762*, r = 0.840*, r = 0.815*) with the per cent moisture content of seed during both the study period (2013 and 2014) and pooled results in D_2 (1st week of July) sown crop (Table 5). The results were in line with the findings of Elanchezhyan *et al*. (2009), who reported significant and positive correlation between moisture content with shoot damage in brinjal.

Crude protein

During the year 2013 crude protein of seed and crude protein of pod wall was positively correlated (r = 0.763*) with the per cent pod infestation in D_1 (3rd week of June) sown crop and (r = 0.735*, r = 0.721*) in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop (Table 5). During 2014 the correlation was significant and positive (r = 0.736*, r = 0.869*) between crude protein content of seed and pod infestation in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop. In the pooled results the correlation was significant and positive (r = 0.740*) between crude protein content of pod wall and pod infestation in D_1 (3rd week of June) sown crop and with the crude protein content of seed, the correlation was significant and positive (r = 0.810* and r = 0.711*) in D_3 (2nd week of July) and D_4 (3rd week of July) sown crop, respectively (Table 5). These finding were in consonance to the findings of Sahoo and Patnaik (2003), who reported significant positive correlation between protein content and incidence of *H. armigera* in pigeonpea. The results were also in harmony with the findings of Kamakshi *et al*. (2008), who reported that proteins exhibited significant positive correlations with pod damage by different pod borers in the different field bean genotypes. Whereas, Jagtap *et al*. (2014) reported that the genotypes having more protein content in buds were preferred least by *H. armigera* larvae than genotypes having lesser protein content.

Fat content

The fat content in seed and in pod wall showed a significant and negative association (r = -0.823*, r = -0.733*) and (r = -0.735*) with pod infestation in D_1 (3rd week of June) and D_2 (1st week of July) sown crop during the year 2013 (Table 5). During the year 2014 a significant and negative correlation (r = -0.860*) and (r = -0.734*) was observed between the fat content of seed as well as pod wall with pod infestation in D_1 (3rd week of June) and D_2 (1st week of July) sown crops. Results of pooled over years of fat content of seed and pod wall also showed a significant and negative association (r = -0.884**) and (r = -0.743*) with the pod infestation in D_1 (3rd week of June) and D_2 (1st week of July) sown crops, respectively. The results are in line with the findings of Kamakshi *et al*. (2008), who reported negative and significant correlation of pod borer complex damage with the fat content in field bean.

Phenol content

The concentration of phenol content in the seed as well as in the pod wall was negatively correlated (r = -0.853*, r = -0.723*) and (r = -0.788*, r = -0.743*) with the pod infestation during the year 2013 in D_1 (3rd week of June) and D_2 (1st week of July) sown crops (Table 5). During 2014 a significant and negative association (r = -0.850*) was observed between phenol content of seed and pod infestation in D_1 (3rd week of June) sown crops. The similar results was also observed of pooled over years. Phenol content of the seed showed significant and negative association (r = -0.900**) with expression of resistance to *H. armigera* in D_1 (3rd week of June) sown crop. Results were in confirmity with the findings of Jagtap *et al*. (2014), who reported that the total phenol content appeared as good indicator of resistance to *H. armigera* in pigeonpea. Similarly, Kamakshi *et al*. (2008) and Sahoo and Patnaik (2003) also reported significant and negative correlation between phenol content of seeds with incidence of *H. armigera*. Verulkar and Singh (2000) reported negative association of phenol content against pod borers in pigeonpea.

Total soluble sugar

The total soluble sugars of seed showed significant and positive association (r = 0.818*, r = 0.735*) with pod infestation caused by *H. armigera* during the year 2013 in D_1 (3rd week of June) and D_2 (1st week of July) sown crops (Table 5). Association between total soluble sugar content of pod wall and pod infestation was highly significant and positive (r = 0.902 r = 0.810) in D_2 (1st week of July) and D_4 (3rd week of July) sown crops. During the year 2014 a significant and positive correlation (r = 0.823*) between total soluble sugar content of seed and pod infestation in D_2 (1st week of July) and between total soluble content of pod wall and pod infestation, the correlation was also significant and positive (r = 0.763*, r = 0.872*, r = 0.812*) in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crops. In pooled results, the correlation between total soluble sugar content of seed and pod infestation was significant and positive (r = 0.738*, r = 0.793*) in D_1 (3rd week of June) and D_2 (1st week of July) sown crops. The association between total soluble sugar content of pod wall and pod infestation was observed highly significant and positive (r = 0.898**, r = 0.819*) in D_2 (1st week of July) and D_4 (3rd week of July) sown crops. The present results vindicated the observation of Sharma *et al*. (2009) that expression of resistance to *H. armigera* was associated with low amounts of sugars in wild relatives of pigeonpea. Similarly the results were also in consonance with Jagtap *et al*. (2014) and Blaney and Simmonds (1990), according to them more total sugar content increased the incidence of *H. armigera* and significant influence of the presence of sugars on feeding behaviour of *H. armigera* larvae in pigeonpea. Dodia (1992) also recorded higher feeding activity of *H. armigera* larvae in pigeonpea when quantity of total soluble sugars was high in the leaves, pods, green seeds and dry seeds. Whereas, the contrasting ensues were postulated by Nanda *et al*. (1996), who found significant negative correlation between total soluble sugars of the pod wall and pod damage due to *H. armigera* in pigeonpea.

Tannin content

The tannin content of the seed as well as pod wall showed significant and negative association (r = -0.828*) and (r = -0.739*) with expression of resistance to *H. armigera* during 2013 in D_2 (1st week of July) sown crop (Table 5). However, during 2014 the resistance was observed with only the tannin content of seed (r = -0.911**, r = -0.775*, r = -0.748*) in D_1 (3rd week of June), D_2 (1st week of July) and D_4 (3rd week of July) sown crops. The pooled results of two years (2013 and 2014) also showed a significant and negative association (r = -0.792*, r = -0.812*) between pod infestation caused by *H. armigera* and tannin content of seed in D_1 (3rd week of June) and D_2 (1st week of July) sown crops. The findings were in close agreement with the results of Jagtap *et al*. (2014) and Kamakshi *et al*. (2008), who reported that higher total tannin content was good indicator of resistance to *H. armigera* and infestation was negatively correlated with the total tannin content in the pigeonpea and field bean genotypes. Besides them, Sahoo and Patnaik (2003) also reported significant and negative correlation between tannin content of seeds with incidence of *H. armigera*. These findings were also in confirmation with the findings of Dodia *et al*. (1998), who reported the higher tannin content in bud in resistant pigeonpea genotypes.

So, from the research findings it can be concluded that the early sowing of the pigeonpea crop could minimize the pod infestation by *H. armigera*. Variety AL-201 can be grown as a preferred variety as compared to other pigeonpea varieties. The glandular (type A), non-glandular (type B) trichomes and pod wall thickness were associated with the resistance against *H. armigera*. In the biochemical constituents, the high amount of fat, phenol and tannin contents were also associated with the resistance against *H. armigera*, whereas, the higher amount of total soluble sugar content of seed as well as pod wall is associated with the susceptibility to the pod borer.

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