International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Online International Journal Available at http://www.cibtech.org/jfav.htm
2012 Vol. 2 (1) January-April, pp.92-100/Jagtap et al.
Research Article

CHARACTER ASSOCIATION ANALYSIS OF RESISTANCE TO *HELICOVERPA ARMIGERA* IN PIGEONPEA [CAJANUS *CAJAN* (L.) MILLSP.]

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ABSTRACT
Character association analysis for *per se* resistance to *Helicoverpa armigera* in pigeonpea [*Cajanus Cajan* (L.) Millsp.]" was studied in sixty diverse single plant selections having differential combinations of flower colour, pod colour and leaf thickness selected from F_6 generations of 10 x 10 Indo-African diallel crosses. These diverse lines were grown in two sets in randomized block design with two replications under identical conditions during *kharif* 2009-2010. The *per se* resistance to *Helicoverpa* was estimated as per cent reduction in yield in each genotype due to *Helicoverpa* feeding in net house as compared to yield under controlled condition. The *per se* resistance to *Helicoverpa* was substantiated by feeding the larvae on individual plant parts (pods, flower and buds) in laboratory and taking observations on gain in larval body weight. Data were recorded for five morphological and five biochemical attributes along with *Helicoverpa* resistance as measured through per cent loss in yield. The study indicated highly significant genotypic differences for *per se* resistance to *Helicoverpa* as also for other component characters. The estimates of the phenotypic (PCV) and genotypic coefficient of variation (GCV) were very close indicating lesser juxtaposition of variability by environmental. All the traits, except food protein content evinced higher estimates of heritability. The genetic advance per cent was also high for resistance to *Helicoverpa* and all other allied traits except, food protein content, leaf thickness, pod wall thickness and total sugar content. Resistance to *Helicoverpa* was positively and significantly correlated with gain in larval weight and total sugar contents and significantly negatively correlated with total tannin content and total phenol content. Gain in larval weight was negatively and significantly correlated with total tannin content, total sugar content, total phenol content and pod length. The correlations of total phenol content and total tannin content with total sugar content were also negative and significant. The correlations were significantly positive for pod length and total phenol content with total tannin content; pod wall thickness and petiole length with total sugar content. Thus, lower total sugar content, higher total tannin content and total phenol content with longer pods are good indicator of resistance to *Helicoverpa.* High positive direct effect on resistance to *Helicoverpa* was observed through gain in larval weight, peduncle length and petiole length. Further, all the biochemical attributed exhibited negative direct effect on resistance to *Helicoverpa*. This indicated the importance of biochemical attributes along with pod wall and leaf thickness in breeding resistance to *Helicoverpa* in pigeonpea

INTRODUCTION
The productivity of pigeonpea has been stagnant primarily due to narrow genetic base. The biotic factors in general and pests in particular restrict the attainable yield. Among the pests *Helicoverpa* is the most dreaded one that ravage the crop irreversibly in all most all the stages. Consequent upon its polyphagous nature, it is difficult to control the pest with conventional insecticides. Farmers often resort to heavy and indiscriminate use of insecticides to control the pest. The extent of pollution and mind boggling expenditure in terms of chemical adds lot to the cost of production. The looming large the constant threat of development of resistance against the insecticides further asks for thinking of developing genetic resistance for managing this dreaded pest but for adequate precise selection criterion.
The inherent *per se* resistance to *Helicoverpa* is the most conspicuous character for realizing attainable productivity, though practically it is very arduous to select for *per se* resistance to *Helicoverpa* under field conditions. Empirically, resistance to *Helicoverpa* is determined by many non-preferential traits that may include both morphological and biochemical attributes. Path coefficient analysis partition the variability in to cause and affect so as to ascertain direct and indirect

effects of a particular contributing trait to arrive at a consummate picture of different contributing traits that can be used for precise and effective selection.

Broadening of narrow genetic base was successfully done in Gujarat by crossing exotic lines from Kenya (ICP-9140; ICP-9135), Tanzania (ICP-12116; ICP-12161), Myanmar (ICP-11488) and Canada (ICP-13555) with diverse indigenous genotype (GT-100, GT-101, Banas and ICP-11912). The sixty single plant selections (SPS) in F_6 generation from these crosses selected for different combinations of morphological and biochemical as evident from pigments on different parts of the plants was used to ascertain the criteria of selection for resistance to *Helicoverpa*.

MATERIALS AND METHODS

The present study was conducted at the Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, during *kharif* 2009-2010. The experimental material for the present study comprised 60 single plant selections (SPS) in F_6 generations of 10 x 10 diallel encompassing exotic lines from Kenya (ICP-9140; ICP-9135), Tanzania (ICP-12116; ICP-12161), Myanmar (ICP-11488) and Canada (ICP-13555) and diverse indigenous genotypes (GT-100, GT-101, Banas and ICP-11912). The African germplasm though had very long duration yet evinced immense complimenting ability of variability to Indian counterparts for yield components. The SPS were peculiar of having varied pigments on flowers, pods and seeds with drastic differences for thickness of leaves that are critical from *Helicoverpa* resistance point of view (Acharya *et al.,* 2008). The details of the SPS were given in Table 1.

The trial was laid out in a randomized block design with two replications by accommodating each entry in a single row plot of 2m length spaced 90 cm apart with intra-row spacing as 30 cm. The resistance to *Helicoverpa* was estimated by growing different SPS progenies in two sets under identical conditions. One set was covered with insect proof net house and was exposed to feeding to *Helicoverpa* by releasing *Helicoverpa.*

The *per se* resistance to *Helicoverpa* was estimated as per cent reduction in yield in each genotype due to *Helicoverpa* feeding in net house as compared to yield of the same genotype under controlled condition. The *per se* resistance to *Helicoverpa* was further substantiated by feeding the larvae on individual plant parts (pods, flower and buds) in laboratory and taking observations on growth of larvae in terms of gain in body weight. The susceptibility was calculated as per cent loss in yield due to *Helicoverpa* as compared to control. The observations were also recorded under laboratory condition for controlled feeding of 4^{th} instar larvae of *Helicoverpa* on pods for 10 days as evident by gain in weight of larvae. The estimated *per se* resistance in each genotype were utilized for studying resistance to *Helicoverpa* vis-a-vis different morphological components viz., petiole length (cm), pod length (cm), pod wall thickness (mm), peduncle length (cm) and leaf thickness (mm) and biochemical attributes viz., total phenol content (%), total tannin content.(%), total sugar content (%), food protein content (%), gain in larval weight (mg) and *Helicoverpa* resistance as measured through per cent loss in yield. The mean values of five randomly selected plants were used for statistical analysis including path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Genotypic differences were highly significant for resistance to *Helicoverpa* as measured through per cent loss in yield as also for other characters indicating presence of enormous amount of genetic variability in the materials (Table 2). This suggested scope for improvement for resistance to *Helicoverpa* by selection using suitable breeding methods. Significant variation was also observed for different morphological (pod length, peduncle length, petiole length, pod thickness, leaf thickness) and biochemical traits (food protein content, total tannin content, total sugar content and total phenol content) suggesting that these traits can also be exploited by using simple breeding methods. In consonance to the present findings, a wide range of variability for various traits has been observed earlier by Dodia *et al.* (1996), Chougule *et al.* (2004), Subramanian and Mohankumar (2006) and Banu *et al.* (2007). The phenotypic variance followed the trend of genotypic variance and was greater than environmental variance for all the characters including resistance to *Helicoverpa* as measured through per cent loss in yield (Table 3). This indicated lesser juxtaposition of variability by

Table 1: Particulars of genotypes used for studying variation for resistance to *Helicoverpa* in pigeonpea

Sr. No.	Entry	Genotypic Designation	Geographical Designation	Sr. No.	Entry	Genotypic Designation	Geographical Designation
1	SPS -1	GT 100 x ICP 9140	Indian x Kenya	31	SPS -34	ICP 11488 x ICP 13092	Myanmar x Canada
2	SPS -2	GT 100 x Banas	Indian x Indian	32	SPS -35	ICP 9140 x ICP 13555	Kenya x Canada
3	SPS -3	GT 100 x ICP 11488	Indian x Myanmar	33	SPS -36	ICP 9140 x ICP 13092	Kenya x Canada
4	SPS -4	GT 100 x ICP 9135	Indian x Kenya	34	SPS -37	ICP 9140 x ICP 13092	Kenya x Canada
5	SPS -5	GT 101 x ICP 12116	Indian x Tanzania	35	SPS -38	ICP 9140 x ICP 13092	Kenya x Canada
6	SPS -6	GT 101 x ICP 13092	Indian x Canada	36	SPS -39	ICP 9140 x ICP 13092	Kenya x Canada
7	SPS -8	ICP-12116 (x)	Tanzania	37	SPS -40	ICP 9140 x ICP 13092	Kenya x Canada
8	SPS -9	Banas x ICP 9135	Indian x Kenya	38	SPS -41	ICP 9140 x ICP 11488	Kenya x Myanmar
9	SPS -10	GT 101	Indian	39	SPS -42	Banas x ICP 9135	Indian x Kenya
10	SPS -11	ICP 12116 x ICP 9135	Tanzania x Kenya	40	SPS -43	Banas x ICP 9135	Indian x Kenya
11	SPS -12	ICP 13092	Canada	41	SPS -44	Banas x ICP 9135	Indian x Kenya
12	SPS -13	ICP 13092 x ICP 9135	Canada x Kenya	42	SPS -45	Banas x ICP 9135	Indian x Kenya
13	SPS -14	ICP 11488 x ICP 13092	Myanmar x	43	SPS -46	ICP 11912	Indian x Canada
14	SPS -15	ICP 13092 x ICP 9135	Canada x Kenya	44	SPS -47	ICP 11912 x ICP 13092	Indian x Canada
15	SPS -16	ICP 13092 x ICP 13555	Canada x Canada	45	SPS -48	Banas x ICP 13555	Indian x Canada
16	SPS -17	ICP 11488 x ICP 12116	Myanmar x Tanzania	46	SPS -49	ICP 11488 x ICP 13555	Myanmar x Canada
17	SPS -18	Banas	Indian	47	SPS -50	Banas x ICP 12116	Indian x Tanzania
18	SPS -19	ICP 13092 x ICP 13555	Canada x Canada	48	SPS -51	ICP 11912 x ICP 9135	Indian x Kenya
19	SPS -20	Banas x ICP 9135	Indian x Kenya	49	SPS -52	ICP 11912 x ICP 13555	Indian x Canada
20	SPS -22	GT 100	Indian	50	SPS -53	GT 101 x Banas	Indian x Indian
21	SPS -23	GT 100 x ICP 11488	Indian x Myanmar	51	SPS -54	ICP 9140 x ICP 13555	Kenya x Canada
22	SPS -24	GT 100 x ICP 11912	Indian x Indian	52	SPS -55	Banas x ICP 13555	Indian x Canada
23	SPS -25	ICP 13092	Canada	53	SPS -56	GT 100 x GT 101	Indian x Indian
24	SPS -27	ICP 9140	Kenya	54	SPS -57	GT 100 x GT 101	Indian x Indian
25	SPS -28	Banas x ICP 9140	Indian x Kenya	55	SPS -58	GT 100 x ICP 9140	Indian x Kenya
26	SPS -29	Banas x ICP 14488	Indian x Myanmar	56	SPS -60	GT 100 x ICP 11488	Indian x Myanmar
27	SPS -30	Banas x ICP 11912	Indian x Indian	57	SPS -61	GT 100 x Banas	Indian x Indian
28	SPS -31	ICP 13555	Canada	58	SPS -62	GT 100 x Banas	Indian x Indian

29	SPS -32	ICP 13555	Canada	69	SPS -63 GT 100 x ICP 11488	Indian x Myanmar
30	SPS -33	ICP 13555	Canada	60	SPS -64 GT 100 x ICP 11488	Indian x Myanmar

Table 2: Analysis of variance (ANOVA) for resistance to *Helicoverpa* and allied traits in pigeonpea

Source	d.f.	Pod length (cm)	Peduncle length (cm)	Petiole length (cm)	Pod wall thickness (mm)	Leaf thickness (mm)	Food protein content (%)	Total tannin content (%)	Total sugar content (%)	Total phenol content (%)	Gain in larval weight (mg)	Resistance to *Helicoverpa* as measured through per cent loss in yield
Replications	1	0.108	0.035	0.021	6.075	0.000	1.002	0.013	0.542	0.032	0.527	0.404
Genotypes	59	4.962**	2.268**	1.020**	51.38**	0.001**	0.122**	0.767**	1.633**	0.280**	34227**	29.06
Errors	59	0.028	0.020	0.013	1.922	0.000	0.068	0.001	0.043	0.001	222.6**	0.696

*, ** Significant at 0.05 and 0.01 per cent levels, respectively.

Table 3: Range, mean and different components of variance for resistance to *Helicoverpa* and allied traits in pigeonpea

Sr. No	Character	Range	Mean ± S.E.	C.D.	Variance components		
					Phenotypic	Genotypic	Environmental
1	**Pod length (cm)**	3.15-9.05	7.06±0.119	0.337	22.34	22.21	0.13
2	**Peduncle length (cm)**	2.20-6.90	3.67±0.100	0.282	28.31	28.04	0.27
3	**Petiole length (cm)**	2.30-5.75	3.38±0.081	0.229	21.52	21.06	0.46
4	**Pod wall thickness (mm)**	30.00-47.50	39.44±0.980	2.781	13.03	12.42	0.61
5	**Leaf thickness (mm)**	0.24-0.38	0.27±0.006	0.017	10.30	9.16	1.14
6	**Food protein content (%)**	24.90-26.15	25.4±0.184	0.523	1.21	0.75	0.46
7	**Total tannin content (%)**	2.03-3.97	2.79±0.023	0.066	22.19	22.16	0.03
8	**Total sugar content (%)**	5.05-7.62	6.19±0.147	0.416	14.72	14.29	0.43
9	**Total phenol content (%)**	1.01-1.99	1.53±0.024	0.067	24.56	24.51	0.05
10	**Gain in larval weight (mg)**	21.50-403.0	209.7±3.812	10.816	62.68	62.63	0.05
11	**Resistance to *Helicoverpa* as measured through percent loss in yield**	8.43-50.58	27.91±0.590	1.674	37.87	37.75	0.12

Table 4: The estimates of genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability (%), expected genetic advance and expected genetic advance as percentage of mean for resistance to *Helicoverpa* and allied traits in pigeonpea

Sr. No.	Source	GCV (%)	PCV (%)	Heritability (%)	GA	GA (%)
1	**Pod length (cm)**	22.21	22.34	98.9	3.22	45.5
2	**Peduncle length (cm)**	28.04	28.31	98.1	2.10	57.1
3	**Petiole length (cm)**	21.06	21.52	95.8	1.44	42.5
4	**Pod wall thickness (mm)**	12.42	13.03	90.9	9.63	24.4
5	**Leaf thickness (mm)**	9.16	10.30	79.1	0.05	18.5
6	**Food protein content (%)**	0.75	1.21	39.0	0.25	1.00
7	**Total tannin content (%)**	22.16	22.19	99.8	1.27	45.5
8	**Total sugar content (%)**	14.29	14.72	94.2	1.77	28.5
9	**Total phenol content (%)**	24.51	24.56	99.6	0.77	55.1
10	**Gain in larval weight (mg)**	62.63	62.68	99.8	270.4	77.4
11	**Resistance to *Helicoverpa* as measured through per cent loss in yield**	37.75	37.87	99.4	21.64	77.3

Table 5: Genotypic and phenotypic coefficient of correlation for resistance to *Helicoverpa* and allied traits in pigeonpea

Characters		Pod length (cm)	Peduncle length (cm)	Petiole length (cm)	Pod wall thickness (mm)	Leaf thickness (mm)	Food protein content (%)	Total tannin content (%)	Total sugar content (%)	Total phenol content (%)	Gain in larval weight (mg)
Resistance to *Helicoverpa* as measured through percent loss in yield	**rg**	-0.142	0.100	0.216	-0.070	-0.125	-0.092	-0.585**	0.483**	-0.538**	0.616**
	rp	-0.141	0.098	0.209	-0.065	-0.106	-0.057	-0.583**	0.469**	-0.534**	0.613**
Pod length (cm)	**rg**		-0.034	0.100	0.131	-0.248	0.216	0.314**	-0.221	0.003	-0.269*
	rp		-0.034	0.102	0.125	-0.215	0.126	0.310**	-0.218	0.001	-0.267*
Peduncle length(cm)	**rg**			-0.209	-0.173	0.112	0.106	0.025	0.024	0.051	-0.042
	rp			-0.200	-0.162	0.110	0.047	0.026	0.027	0.049	-0.041
Petiole length (cm)	**rg**				0.100	-0.157	-0.130	-0.196	0.345**	-0.167	0.198
	rp				0.104	-0.123	-0.069	-0.193	0.331**	-0.162	0.194
Pod wall thickness (mm)	**rg**					-0.027	0.054	0.087	0.011	-0.029	-0.038
	rp					-0.005	0.058	0.083	0.020	-0.028	-0.036
Leaf thickness (mm)	**rg**						-0.219	-0.004	-0.046	-0.020	-0.100
	rp						-0.129	-0.005	-0.042	-0.015	-0.085
Food protein content (%)	**rg**							-0.030	-0.022	0.108	-0.056
	rp							-0.025	-0.035	0.066	-0.034
Total tannin content (%)	**rg**								-0.709**	0.675**	-0.852**
	rp								-0.686**	0.673**	-0.850**
Total sugar content (%)	**rg**									-0.712**	0.814**
	rp									-0.689**	0.792**
Total phenol content (%)	**rg**										-0.727**
	rp										-0.725**

**** Significant at P = 0.05 and 0.01 levels respectively.**

Table 6: Direct and indirect effects of different traits on resistance to *Helicoverpa* in pigeonpea

Sr. No.	Genotypes	Pod length (cm)	Peduncle length (cm)	Petiole length (cm)	Pod wall thickness (mm)	Leaf thickness (mm)	Food protein content (%)	Total tannin content (%)	Total sugar content (%)	Total phenol content (%)	Gain in larval weight (mg)	Resistance to *Helicoverpa* as measured through percent loss in yield
1	Pod length (cm)	**-0.053**	-0.006	0.016	-0.002	0.022	-0.005	-0.054	0.050	0.000	-0.109	-0.142
2	Peduncle length (cm)	0.002	**0.192**	-0.031	0.003	-0.011	-0.002	-0.005	-0.006	-0.013	-0.017	0.100
3	Petiole length (cm)	-0.005	-0.036	**0.159**	-0.002	0.013	0.003	0.034	-0.076	0.042	0.079	0.216
4	Pod wall thickness (mm)	-0.006	-0.029	0.016	**-0.018**	0.001	-0.002	-0.014	-0.005	0.007	-0.015	-0.070
5	Leaf thickness (mm)	0.011	0.020	-0.019	0.000	**-0.127**	0.005	0.001	0.010	0.004	-0.035	-0.125
6	Food protein content (%)	-0.007	0.008	-0.011	-0.001	0.013	**-0.066**	0.004	0.008	-0.017	-0.014	-0.092
7	Total tannin content (%)	-0.016	0.005	-0.030	-0.001	0.001	0.001	**-0.196**	0.157	-0.157	-0.348	-0.585**
8	Total sugar content (%)	0.011	0.005	0.052	0.000	0.004	0.001	0.120	**-0.261**	0.179	0.324	0.483**
9	Total phenol content (%)	0.000	0.009	-0.025	0.001	0.002	-0.003	-0.117	0.157	**-0.275**	-0.296	-0.538**
10	Gain in larval weight (mg)	0.014	-0.007	0.030	0.001	0.009	0.001	0.149	-0.181	0.189	**0.409**	0.616**

Residual effect = 0.5288 *, ** Significant at P = 0.05 and 0.01 levels respectively.

environmental factors and the phenotypic variability may be considered as a reliable measure of genotypic variability. This was further substantiated by very closer estimates of the phenotypic coefficient (PCV) and genotypic coefficient of variation (GCV) (Table 4).

The highest magnitude of genotypic coefficient of variation was recorded in gain in larval weight (62.63%) followed by resistance to *Helicoverpa* as measured through per cent loss in yield (37.75%). Predominant traits *viz.,* peduncle length (28.04%), total phenol content (24.51%), pod length (22.21%), total tannin content (22.16%) and petiole length (21.06%) exhibited moderate to high genotypic coefficient of variation, while pod thickness (12.42%), leaf thickness (9.16%), total sugar content (14.29%) and food protein content (0.75%) had lower magnitude of genotypic coefficient of variation (Table 4). In agreement to the present findings, Dodia *et al*. (1996) has also reported similar results for gain in larval weight and total phenol content; Banu *et al.* (2007) for total phenol content and Saxena *et al.* (1989) for pod length.

The lesser role of environment in determining phenotypic variability for resistance to *Helicoverpa* and allied traits was further substantiated by higher estimates of heritability in broader sense for all the traits except, food protein content (Table 4). Similar results have been reported by Godawat (1980) and Sidhu *et al.* (1985). The genetic advance per cent was also high for resistance to *Helicoverpa* and all other allied traits except, food protein content, leaf thickness, pod wall thickness and total sugar content (Table 4) indicating simple selection to be an effective tool for improvement for resistance to *Helicoverpa* and allied traits. In consonance to the present findings, Dodia *et al*. (1996) has also reported moderate to high genetic advance for majority of these traits.

The phenotypic and genotypic correlation coefficients were worked out for resistance to *Helicoverpa* and other component characters (Table 5). The results indicated that the estimates of genotypic correlation were slightly higher than their phenotypic counterparts. This indicated a high degree of association at genotypic levels and that its association at phenotypic level is least deflated by the influence of environment. Resistance to *Helicoverpa* as measured through per cent loss in yield was positively and significantly correlated with gain in larval weight and total sugar contents and significantly negative correlation with total tannin content and total phenol content. This indicated that larvae of *Helicoverpa* gain more weight on susceptible genotypes and that lower total sugar content, higher total tannin and total phenol contents are good indicator of resistance to *Helicoverpa*.

Gain in larval weight was negatively and significantly correlated with total tannin content, total sugar contents, total phenol content and pod length. The correlations of total phenol content and total tannin content with total sugar content were also negative and significant. The correlations were significantly positive for pod length and total phenol content with total tannin content; pod wall thickness and petiole length with total sugar content. These findings are in consonance to the results reported by Godawat (1980); Murkute *et al.* (1993) and Vange and Egbe Moses (2009). Thus, lower total sugar content, higher total tannin content and total phenol content with longer pods are good indicator of resistance to *Helicoverpa.* However, correlations of total phenol content and total tannin content with total sugar content were negative. Thus, high volume crossing like biparental mating, diallel selective mating would be desirable to break these undesirable linkages for having appropriate combination of these attributes for breeding resistant genotypes to *Helicoverpa* in pigeonpea. The positive correlation of total tannin content with pod length can be further exploited to have better combination of yield and resistance to *Helicoverpa*. These characters also had high heritability and high expected genetic advance and therefore, need more emphasis during selection programme aiming to improve resistance to *Helicoverpa* in pigeonpea.

The direct and indirect effects of different components on Resistance to *Helicoverpa* as measured through per cent loss in yield are presented in Table 6. High positive direct effect on resistance to *Helicoverpa* as measured through per cent loss in yield was observed through gain in larval weight, peduncle length and petiole length. These three characters had positive and significant correlation with resistance to

Helicoverpa as measured through per cent loss in yield. Further, all the biochemical attributed exhibited negative direct effect on resistance to *Helicoverpa* as measured through per cent loss in yield.

This indicated the importance of biochemical attributes like food protein content, total tannin content, total sugar content and total phenol content along with pod wall and leaf thickness in breeding resistance to *Helicoverpa* in pigeonpea. The importance of total tannin content and total phenol content was further substantiated by their conspicuous indirect contribution to resistance to *Helicoverpa* as measured through per cent loss in yield. However, the indirect positive contribution of gain in larval weight and total sugar content to resistance to *Helicoverpa* as measured through per cent loss in yield need due consideration in breeding programme.

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