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Antixenosis and antibiosis as a resistance mechanism to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in some maize genotypes

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Abstract
Twenty four local maize genotypes were screened for resistance/ susceptibility against *C. partellus* with respect to antixenosis and antibiosis mechanisms. The results revealed that the genotypes CM- 133 and CM-123 were highly resistant with Leaf Damage Score (LDS) of 0.93 and 0.86, respectively, whereas Basi-local was observed extremely susceptible with 8.86 LDS. The overall contribution 88.91 per cent towards the damage of *C. partellus* was obtained in combination of all significant characters including stem diameter, internodal distance, number of nodes, cob length, leaf length, leaf width and leaf trichome density. Highest phenolic content (antibiosis) of 238.05 and 234.76 µg/g was recorded in highly resistant genotypes CM-123 and CM-133, respectively while as, extremely susceptible genotype Basi-local exhibited lowest phenolic content 117.27 µg/g. Significant and negative correlation was observed between phenol content and leaf damage score at 1 per cent level of significance.

Keywords: Resistance, *Chilo partellus,* antixenosis, antibiosis, Leaf Damage Score

1. Introduction

Maize is a multipurpose crop, providing food and fuel for human beings, feed for animals, poultry and livestock. It is a short duration, seasonal crop with high yielding potential and can provide good return to the growers with relatively little input and investment. Maize is used in the preparation of starch, glucose, corn feed, and corn gluten and forms a major ingredient in poultry region, and being a source of starch and protein is used as fodder for livestock. Maize is a versatile crop grown over a range of agro climatic zones. In fact the suitability of maize to diverse environment is unmatched by any other crop. Maize grains have great nutritional value and are used as raw material for manufacturing many industrial products. In India, maize is the third most important cereal crop after rice and wheat cultivated on an area of 8.3 million hectares with a production of 21 million tonnes with average yield of 2.5 tonnes per hectare [5]. In Jammu and Kashmir State maize occupies an area of 0.32 million hectares with a production of 0.55 million tonnes and productivity of 1.75 tonnes per hectare [6], besides 85 per cent of maize crop is grown in rainfed areas and ranks second most important crop after paddy. Productivity of maize in Kashmir valley under rainfed conditions is 11.5 quintals per hectare as against 23 quintals per hectare in sub-tropics of Jammu [7]. The plant is attacked by 140 species of insect pests causing varying degrees of damage however, only about a dozen of them are quite serious causing damage from sowing till storage [21]. The damage may be caused by certain insects attacking roots (rootworms, wireworms, white grub and seed corn maggots), leaves (aphids, armyworm, stem borers, thrips, spider mites and grasshoppers), stalks (stem borers and termites), ear and tassel (stem borers, earworms, adult rootworms and armyworm) and grain during storage (grain weevils, grain borers, Indian meal moth and angoumois grain moth). Insect damage can occur at any stage of maize production and storage. Its severity depends on germplasm used, cultivation practices, level of pest infestation, control strategies used and climate [8]. Maize crop is most vulnerable to maize stem borer *Chilo partellus* (Swinhoe) and cause severe losses [22]. A yield loss of 24-74 per cent has been reported alone by this pest [14.15]. Nature of damage and behaviour of this pest makes it very difficult to control by conventional insecticides and biological control agents. Thus, there is a need to develop alternative management strategies.

Host plant resistance against various pests including insects has remained a reliable source for pest management since the advent of modern agriculture. The use of insect resistant cultivar is an essential component of IPM which offers an economic, stable and ecologically sound approach to minimize the damage caused by the borers. The use of insect resistant cultivar is an essential component of IPM which offers an economic, stable and ecologically sound approach to minimize the damage caused by the borers. There are many plant characters which are responsible for host plant resistance. The plant structures may influence positively as well as negatively on herbivores and their natural enemies [1]. These characters may be divided into morphological and biochemical basis of resistance of the host plant which significantly exhibit resistance to *C. partellus* in maize and show variable degree of preference against the pest. Morphological characters are most important in host plant resistance to *C. partellus* [17] and are known to contribute a lot towards the host plant resistance [23, 18]. In maize these characters are responsible for suitability of a cultivar for feeding, oviposition and development. Trichome densities and surface waxes are considered to have negative effect on the oviposition and development of *C. partellus* [13]. Similarly, tunnel length, stem thickness, plant height and length of 3rd internode at crop maturity have negative impact on the infestation of pest [3]. Biochemical factors such as phenols and sugars also play an important role in plant defense mechanism to *C. partellus* [12]. Keeping in view the above facts, the study was conducted on 24 genotypes of maize with the objective to find the role of various physico-chemical plant factors contributing resistance/susceptibility against the pest.

2. Material and Methods

Field experimentation: The present investigation was carried out in the experimental field of Dryland (*Karewa*) Agricultural Research Station (DARS), Budgam a constituent of SKUAST-Kashmir, Shalimar situated at an altitude of 1560 meters above mean sea level during 2014. A total of twenty four maize genotypes were screened against maize stem borer (*C. partellus*) under natural infestation condition. The experimental site during maize growing season recorded maximum temperature of 34ºC to minimum of 14ºC with a relative humidity of 40- 45%. The sowing of the experimental material was carried in plots of 3×2 m on 20th May 2014 in Randomized Block Design with three replications of each genotype maintaining row to row and plant to plant distance of 60 and 20 cm, respectively. Other agronomical practices were carried out as per the package of practices recommended by Division of Agronomy, SKUAST-Kashmir, Shalimar. However, no insecticidal treatment was given to the experimental material.

Leaf damage score: Data on leaf damage was taken on visual ratings score at an interval of 20, 30 and 40 Days After Sowing (DAS) on five infested plants per plot as per scale of 0-9 (Table-1) as recommended by CIMMYT [11]. On the basis of rating score, the accessions were grouped as extremely resistant, highly resistant, resistant, moderately resistant, susceptible, highly susceptible and extremely susceptible.

Morphological plant characters: In order to determine a relationship between plant characters and their relative susceptibility to *C. partellus* all the 24 maize genotypes were raised at the experimental area of Dryland (*Karewa*) Agricultural Research Station (DARS), Budgam during the year 2014 in Randomized Block Design with three replications each and observations in respect of following physical characters were recorded at 75 days after sowing on five randomly selected plants per plot. These included leaf trichome density, no. of nodes per plant, intermodal distance, stem diameter, leaf length, leaf width, cob height, cob length, length of central spike and plant height. Trichome density count was carried by cutting the leaf below the first ear at the centre of the blade and a cork borer of 1cm diameter was used to punch maize leaf disc for which the number of trichome hairs were counted under a dissecting microscope. Total number of nodes per plant were recorded starting from node 1st. The internodal distance was measured with the help of measuring tape. The stem diameter was recorded with the help of vernier caliper by measuring from the centre of 3rd internode. The measurement of leaf length and leaf width from leaf at the cob node was carried with the help of measuring tape. Cob height was taken as a distance between node one and cob node with the help of measuring tape. Cob length of central spike, plant height was also recorded with the help of measuring tape.

Total phenolic content: Total phenols were estimated from leaf sheath at 40 DAS**.** Fresh leaves (0.5 g) were homogenized in 3 ml of 80 per cent methanol and agitated for 15 minutes at 70 ºC. The solution was centrifuged at 10,000 rpm for 10 minutes and the supernatant collected. The supernatant was used for the estimation of total phenols. The phenolic content was estimated as per Zieslin and Ben-Zaken [24] method. One ml of methanol extract was added to 2 ml of 2 per cent sodium carbonate (Na_2CO_3). The solution was incubated for 5 minutes at room temperature after which 0.1 ml of 1 N Folin-Ciocalteau reagent was added. The solution was incubated again for 10 minutes and absorbance of the blue color was measured at 760 nm. Phenolic concentration was determined from standard curve prepared with gallic acid and was expressed as µg Gallic acid equivalents g^{-1} FW (µg GAE g^{-1} FW).

2.1 Statistical analysis of data

Research data was subjected to the analysis of variance and difference was compared at 1 per cent level of significance by using OPSTAT software. Simple correlation between morphological characters and total phenol content with leaf damage score of maize stem borer (*C. partellus*) was worked out. Multiple linear regression analysis was also worked out between morphological characters and leaf damage by using SPSS (v10.0) software.

3. Results and Discussion

The present studies (Table-2 and Fig-1) revealed a wide range of variation in susceptibility among 24 genotypes of maize against *C. partellus* however, leaf damage score ranged between 0.33 to 3.26, 0.60 to 7.26 and 0.86 to 8.86 at 20, 30 and 40 DAS, respectively. All the genotypes lacked immunity, but CM-133 and CM-123 was categorized as highly resistant, whereas, Basi-local extremely susceptible to the pest. Initially at 20 DAS undamaged to pin holes on 1 or 2 leaves were found on resistant genotypes which later at 30 DAS changed to small rounded holes followed by small and large rounded holes at 40 DAS. On the other hand, on susceptible genotypes, initial small to large rounded holes increased first to large round and large lesions and then to large elongated lesions at 20, 30 and 40 DAS, respectively. The present results are almost in consonance with the studies of Lella and Srivastav [16] who recorded leaf damage score of 1 to 2.2, 1.4 to 4.2, 2.6 to 6.6 at 20, 30 and 60 DAS in different maize genotypes. Similarly Chavan *et al.* [10] also identified various resistant maize genotypes on the basis of leaf injury rating on 1-9 rating scale in different maturity groups and observed a range from 2.4 to 6.4 which also support our findings.

Significant variations were observed in all the morphological plant characters (Table-3) and phenolic content (Table-4) of different genotypes of maize. Stem diameter, internodal distance, number of nodes per plant, cob length, leaf length, leaf width and leaf trichomes showed negative and significant correlation registering r-values of -0.891**, -0.502**, -0.485**, -0.655**, -0.628**, -0.718** and -0.625**, respectively at 1 per cent level of significance. However, cob height, length of central spike and plant height showed non-significant and negative correlation with leaf damage. Ali *et al.* [4] found partial conformity results that stem diameter and length of central spike was positively correlated but we find negative correlation of stem diameter and length of central spike with *C. partellus* infestation but Afzal *et al.* [2] showed statistically negative and significant correlation of pest infestation with stem diameter.

Samples were collected for analysis at 40 DAS of 24 genotypes of maize to determine the total phenol content by Folin- Ciocalteau reagent method (Zieslin and Ben-Zaken [24]). Perusal of data in Table-4 revealed that total phenol content in maize leaf sheath at 40 DAS was minimum 117.97µg/g in extremely susceptible genotype Basi-local as against maximum 238.05 and 234.76 µg/g of fresh weight in highly resistant genotypes CM-123 and CM-133, respectively. Resistant genotypes KDM-402, KDM-362B, KDM-381A and KDM-895A recorded a total phenol content of 196.14, 213.30, 221.83 and 222.95 µg/g of fresh weight, respectively. KDM-402 and KDM-362B differed significantly from KDM-381A and KDM-895A (Fig-2). The finding is analogous to the observations made by Bergvinson [9], Santiagoa *et al.* [20] and Rios *et al.* [19] who found that total phenols improve resistance towards the borer. Total phenolic content in leaf sheath at 45 DAS had significant and negative correlation with leaf damage score of *C. partellus* with r- value of -0.812** at 1 per cent level of significance (Table-6)

Multiple regression analysis (Table-7) showed that overall 88.91 per cent contribution towards the damage of *C. partellus* was exhibited in combination of all the significant characters stem diameter, internodal distance, number of nodes per plant, cob length, leaf length, leaf width and leaf trichome density. However, leaf trichomes contributed maximum individual effect of resistance to the tune of 40.76 per cent followed by stem diameter 34.72 per cent towards the damage of pest. These results are almost in conformity with those of Parvez [17] and Afzal *et al.* [2] who reported that morphological characters of the plant were the most important factor which accounted for resistance contribution to the tune of 60.64 and 84.8 per cent, respectively.

Table 1: Scale for scoring intensity of damage on leaves (CIMMIYT [11])

S. No.	Visual rating of damage	Numerical score	Resistance reaction
1.	No damage	0	Extremely resistant
2.	Few pin hole or fine hole of injury on 1-2 leaves	1	Highly resistant
3.	Few small holes on few leaves	2	Resistant
4.	Few leaves with several small holes	3	Resistant
5.	Several leaves with holes	4	Moderately resistant
6.	Few leaves with elongated lesions	5	Moderately resistant
7.	Several leaves with elongated lesions	6	Susceptible
8.	About half of leaves with long lesions/tattering	7	Susceptible
9.	Most of leaves with long lesions or severe tattering	8	Highly susceptible
10.	Most leaves with long lesions or lodged or plant dying due to severe damage	9	Extremely susceptible

Table 2: Relative susceptibility of different maize genotypes to stem borer *Chilo partellus* (Swinhoe) on the basis of leaf damage score at Dryland (*Karewa*) Agricultural Research Station, Budgam during 2014

S. No.	Genotype	Leaf damage score		
		20 DAS	30 DAS	40 DAS
1.	KDM-914A	2.66[d]	5.33[f]	5.80[f]
2.	CM-133	0.33[a]	0.60[a]	0.93[a]
3.	CM-123	0.33[a]	0.66[a]	0.86[a]
4.	CM-128	2.53[d]	3.66[d]	3.93[d]
5.	C-15	2.86[e]	5.66[g]	7.06[h]
6.	SMC-3	2.60[d]	4.66[e]	5.13e
7.	KDM-962A	2.93[e]	5.26[f]	6.00[f]
8.	Basi-local	3.26[g]	7.26[i]	8.86[j]
9.	KDM-72	2.46[d]	4.73[e]	5.13[e]
10.	KDM-340A	2.93[e]	6.46[h]	8.06[i]
11.	C-6	2.53[d]	4.66[e]	5.13[e]
12.	KDM-895A	0.73[b]	1.26[b]	1.86[b]
13.	KDM-347	3.06[f]	6.66[h]	8.13[i]
14.	KDM-381A	0.60[b]	1.26[b]	1.86[b]
15.	KDM-322	2.80[e]	5.66[g]	7.06[h]
16.	KDM-1263	3.00[f]	5.66[g]	7.13[h]
17.	KDM-912A	2.73[e]	5.46[f]	5.93[f]
18.	KDM-361A	3.06[f]	6.53[h]	7.93[i]
19.	KDM-916A	2.86[e]	5.73[g]	7.06[h]
20.	KDM-362B	0.66[b]	1.33[b]	1.73[b]
21.	KDM-402	1.60[c]	2.33[c]	2.93[c]
22.	KDM-463	2.73[e]	5.26[f]	6.06[g]
23.	KDM-935A	3.00[f]	6.60[h]	8.06[i]

24.	SMH-2	2.60^{d}	3.53^{d}	3.93^{d}
	$CD_{(P=0.05)}$	0.20	0.24	0.22

The value in individual columns superscripted by similar letter(s) do not differ
Each figure is the mean of three replications significantly

Table 3: Morphological characters of different maize varieties/genotypes screened during 2014

S. No.	Genotypes	Leaf Trichome density (cm^{-2})	No. of nodes/ plant	Inter-nodal distance (cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width (cm)	Cob height (cm)	Cob length (cm)	Length of central spike of tassel (cm)	Plant height (cm)
1	KDM 914A	61.60^{e}	13.66^{d}	9.76^{d}	20.58^{d}	78.13^{d}	8.44^{d}	66.66^{d}	21.40^{d}	29.53^{d}	133.32^{d}
2	CM-133	93.06^{k}	14.80^{f}	12.73^{h}	23.93^{i}	91.00^{i}	9.62^{j}	93.42^{i}	26.40^{i}	34.26^{i}	188.44^{i}
3	CM-123	94.33^{k}	14.86^{f}	12.73^{h}	23.87^{i}	91.13^{i}	9.68^{j}	92.87^{i}	26.26^{i}	34.33^{i}	185.75^{i}
4	CM-128	77.80^{a}	14.26^{e}	11.15^{f}	21.68^{f}	84.60^{f}	8.74^{f}	79.49^{f}	23.13^{f}	31.26^{f}	158.99^{f}
5	C-15	53.93^{c}	13.66^{d}	9.13^{c}	20.17^{c}	76.73^{c}	8.14^{c}	62.35^{c}	20.53^{c}	29.33^{d}	124.71^{c}
6	SMC-3	73.46^{g}	14.26^{e}	10.56^{e}	21.17^{e}	81.23^{e}	8.61^{e}	75.29^{e}	22.53^{e}	30.66^{e}	150.58^{e}
7	KDM-962A	62.80^{e}	13.66^{d}	9.70^{d}	20.62^{d}	78.40^{d}	8.43^{d}	66.25^{d}	21.46^{d}	29.46^{d}	132.50^{d}
8	Basi-local	41.33^{a}	12.66^{a}	8.36^{a}	18.46^{a}	71.60^{a}	7.18^{a}	52.91^{a}	18.53^{a}	27.26^{a}	105.44^{a}
9	KDM-72	72.00^{g}	14.26^{e}	10.55^{e}	21.26^{e}	81.26^{e}	8.59^{e}	75.22^{e}	22.40^{e}	30.60^{e}	150.44^{e}
10	KDM-340A	46.66^{b}	13.13^{b}	8.73^{b}	19.34^{b}	76.46^{c}	7.62^{b}	57.31^{b}	19.33^{b}	28.13^{b}	114.62^{b}
11	C-6	72.46^{g}	14.26^{e}	10.56^{e}	21.16^{e}	81.46^{e}	8.59^{e}	75.29^{e}	22.53^{e}	30.73^{e}	150.58^{e}
12	KDM-895A	86.00^{j}	14.33^{f}	11.58^{g}	22.68^{h}	87.03^{h}	9.40^{i}	82.97^{h}	24.53^{h}	33.46^{h}	165.94^{h}
13	KDM-347	46.73^{b}	13.06^{b}	8.76^{b}	19.24^{b}	74.93^{b}	7.61^{b}	57.20^{b}	19.60^{b}	28.13^{b}	114.40^{b}
14	KDM-381A	85.46^{j}	14.33^{f}	11.48^{g}	22.67^{h}	87.56^{h}	9.32^{h}	82.25^{h}	24.60^{h}	33.46^{h}	164.50^{h}
15	KDM-322	56.60^{d}	13.66^{d}	9.16^{c}	20.14^{c}	76.73^{c}	8.09^{c}	62.56^{c}	20.53^{c}	29.40^{d}	125.12^{c}
16	KDM-1263	55.93^{d}	13.66^{d}	9.20^{c}	20.19^{c}	76.86^{c}	8.14^{c}	62.83^{c}	20.60^{c}	29.46^{d}	125.67^{c}
17	KDM-912A	63.20^{f}	13.66^{d}	9.60^{d}	20.63^{d}	78.26^{d}	8.44^{d}	65.56^{d}	21.46^{d}	29.26^{d}	131.13^{d}
18	KDM-361A	46.60^{b}	13.20^{b}	8.76^{b}	19.24^{b}	74.93^{b}	7.59^{b}	57.81^{b}	19.40^{b}	28.53^{c}	115.63^{b}
19	KDM-916A	53.93^{c}	13.40^{c}	9.20^{c}	20.12^{c}	76.73^{c}	8.14^{c}	61.64^{c}	20.46^{c}	29.33^{d}	123.28^{c}
20	KDM-362B	86.00^{j}	14.26^{e}	11.36^{f}	22.66^{h}	87.33^{h}	9.38^{h}	80.99^{g}	24.46^{g}	33.46^{h}	161.99^{g}
21	KDM-402	80.46^{i}	14.33^{f}	11.23^{f}	22.18^{g}	86.10^{g}	9.10^{g}	80.46^{g}	24.06^{g}	32.60^{g}	160.92^{g}
22	KDM-463	62.00^{e}	13.66^{d}	9.73^{d}	20.60^{d}	77.80^{d}	8.43^{d}	66.46^{d}	21.46^{d}	29.26^{d}	132.91^{d}
23	KDM-935A	46.40^{b}	13.06^{b}	8.73^{b}	19.30^{b}	75.20^{b}	7.62^{b}	57.00^{b}	19.66^{b}	27.93^{b}	114.01^{b}
24	SMH-2	78.40^{h}	14.06^{e}	11.13^{f}	21.72^{f}	84.40^{f}	8.72^{f}	78.24^{f}	23.26^{f}	31.13^{f}	156.48^{f}
	$CD_{(p=0.05)}$	1.56	0.22	0.26	0.14	0.66	0.07	1.38	0.42	0.47	2.79

Each figure is the mean of three replicate the value in individual columns superscripted by similar letter(s) do not differ signifi

Table 4: Total phenol of leaf sheath of different maize genotypes screened against stem borer *Chilo partellus* (Swinhoe) at DARS Budgam during 2014

S. No.	Genotypes	Total phenol content (μg/g)
1.	KDM-914A	157.90^{b}
2.	CM-133	234.76^{e}
3.	CM-123	238.05^{e}
4.	CM-128	180.96^{c}
5.	C-15	143.56^{b}
6.	SMC-3	166.43^{b}
7	KDM-962A	158.18^{b}
8.	Basi-local	117.97^{a}
9.	KDM-72	170.27^{c}
10.	KDM-340A	123.87^{a}
11.	C-6	169.24^{c}
12.	KDM-895A	222.95^{e}
13.	KDM-347	130.81^{a}
14.	KDM-381A	221.83^{e}
15.	KDM-322	146.46^{b}
16.	KDM-1263	137.84^{a}
17.	KDM-912A	155.84^{b}
18.	KDM-361A	128.00^{a}
19.	KDM-916A	136.53^{a}
20.	KDM-362B	213.30^{d}
21.	KDM-402	196.14^{d}
22.	KDM-463	151.90^{b}
23.	KDM-935A	127.25^{a}
24.	SMH-2	177.58^{c}
	$CD_{(P=0.05)}$	23.48

Each figure is the mean of three replications,
The value in individual columns superscripted by similar letter(s) don't differ significantly

Table 5: Correlation coefficient values between Leaf damage score of *Chilo partellus* (Swinhoe) and morphological plant characters during 2014

Plant characters	r-value
Cob height(cm)	-0.091*
Length of central spike (cm)	-0.284*
Plant height (cm)	-0.293*
Stem diameter (mm)	-0.891**
Internodal distance (cm)	-0.502**
Number of nodes/plant	-0.485**
Cob length (cm)	-0.655**
Leaf length (cm)	-0.628**
Leaf width (cm)	-0.718**
Leaf trichome density (cm^{-2})	-0.625**

* = non-significant
**= significant at 1 per cent level

Table 6: Correlation between total phenol content of maize genotypes in relation to leaf damage score by Stem borer, *Chilo partellus* (Swinhoe) during 2014

	Total phenol content (µg/g)	Leaf damage score
	X_1	X_2
X_1		-0.812**
X_2	-0.812**	

** Significant at 1 per cent

Table 7: Multiple linear regression analysis between leaf damage and plant characters along with coefficient of determination

	Regression equation	R^2	100 R^2	Difference
Y=	7.925-1.541**X1	0.3472	34.72	34.72
Y=	4.196-1.251X1-0.464X2	0.3581	35.81	1.09
Y=	8.415-0.904X1-0.206X2-2.01**X3	0.4051	40.51	4.70
Y=	8.558-1.103X1-0.351X2-1.451X3-0.6518X4	0.4521	45.21	4.70
Y=	11.65-1.418X1+0.474X2+1.75X3-0.5518X4+0.4395X5	0.4785	47.85	2.64
Y=	12.51-0.811X1-0.381X2-1.31X3+0.851X4-0.458X5-1.0381X6	0.4815	48.15	0.30
Y=	8.876-1.651X1+0.561X2-1.85X3-0.4581X4-0.445X5+1.329X6-0.481**X7	0.8891	88.91	40.76

**=Significant at p<0.01, R^2= Coefficient of Determination, X1= Stem diameter, X2= Internodal distance, X3= Number of nodes per plant, X4= Cob length, X5= Leaf length, X6= Leaf width, X7= Leaf trichome density

4. Conclusion

It was concluded that several mechanisms of resistance exist in temperate maize genotypes with trichome density being the most promising indicator of resistance followed by stem diameter. Total phenols have a negative influence on the pest infestation. More research is needed to identify and combine different mechanisms into new inbred lines for hybrid production.

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