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Inheritance studies on resistance to turcicum leaf blight in semi-temperate genotypes of maize (*Zea mays*)*

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Turcicum leaf blight (*Helminthosporium turcicum* pass or *Exserohilum turcicum*) of maize (*Zea mays* L.), also known as northern corn leaf blight is the major foliar disease of maize in the plains of India and in Himalayan region, especially Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, Meghalaya, Tripura and Assam. Production of maize in hilly areas is low as compared to the other parts of the country. The major cause of low yield is Turcicum leaf blight which causes high (28–91%) yield losses (Pant *et al.* 2000 and Singh *et al.* 2004). Most of the maize cultivars, particularly early maturing, have been found highly susceptible.

The disease can be managed to some extent by chemicals and cultural methods. However, genetic resistance is best option as it is not only durable but also cost-effective. It also complements all other methods in an integrated manner. Several studies have been conducted to understand the nature of inheritance of resistance against this disease (Sharma and Payak 1990). The results on inheritance studies differ with regard to relative role of various genetic components. Secondly, involvement of early germplasm which dominate the maize production in the hills is also very scanty in such studies. Therefore, the present investigation was undertaken to understand the nature and type of gene action governing resistance to *H. turcicum* and to develop a sound resistance breeding programme to evolve high-yielding early maize cultivars resistant to *H. turcicum.*

Four susceptible inbreds 'CM 128', 'V 327', 'V 17' and 'V 128' and 2 resistant inbreds, 'V 335' and 'V 13' were used to develop the F_1 crosses and their segregating generations. These lines, evolved under hilly environment were selected on the basis of their disease reaction and early maturity. These 6 inbreds were crossed in all possible combinations to get 15 F_1 crosses (excluding reciprocals) during winter (*rabi*) 1998–99. During rainy *(kharif)* 1999, 15BC_1's and 15 BC_2's were developed along with the advancement of F_1 generation by bulk pollinations to obtain 15 F_2's at Hawalbagh. Fifteen F_1's, 15 F_2's, 15 BC_1's, 15 BC_2's, and 6 parents (4 susceptible and 2 resistant) were evaluated in a randomized block design during *kharif* of 2000 at Research Farm of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Hawalbagh, Almora and during the *rabi* 2000–01 at Sihora Farm, Rudrapur with 2 replications. Row-to-row spacing of 60 cm and plant-to-plant of 25cm was maintained. Two rows of infectors 'Dihari Local' and 'VL Amber Popcorn' were planted after every 6 plots. Recommended fertilizer doses of 160 kg N, 60 kg P_2O_5 and 40 kg K_2O was applied.

Inoculum was used in different ways for creating artificial epiphytotic conditions in field.

Culture of pathogen on sorghum grains, on artificial medium, like potato dextrose agar (PDA), spores obtained from fresh leaves in water and powdered old leaves carrying blight lesions, and mature leaves heavily infected with leaf blight were collected in the previous season. These leaves were sun-dried and grounded to get coarse powder for using it as inoculum.

A pinch of the leaf powder was dropped into the leaf whorl of each plant, commencing from 20th day after planting. To ensure better disease development, spore suspension was

Table 1 Analysis of variance (ANOVA) for turcicum leaf blight

Source	DF	MSS	
		Kharif 2000	*Rabi* 2000–01
Replications	1	0.0087	0.0001
Treatments	65	1.2657**	0.8252**
Error	65	0.0072	0.0017
CV (%)		2.65	5.33
CD (*P*=0.05)		1.66	0.08
CD (*P*=0.01)		2.26	0.11

**P=0.05

*Shortnote

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Table 2 Estimates of gene effects in 15 crosses for turcicum leaf blight during *kharif* 2000 and *rabi* 2000–01

Cross	m	d	h	i	j	l	Type of epistasis
			Kharif 2000				
'CM 128' × 'V 327'	4.1844**	–0.1220**	–1.3360**	–0.2500**	0.2937**	1.0138**	D
'CM 128' × 'V 335'	3.8312**	0.9313**	–5.4088**	–0.9500**	–0.8525**	4.2525**	D
'CM 128' × 'V 13'	3.0981**	0.9344**	–1.5094**	0.2200**	–1.7088**	1.1863**	D
'CM 128' × 'V 128'	4.3531**	–0.1406**	–1.1669**	–0.4000*	0.1013**	1.0013**	D
'CM 128' × 'V 17'	4.2331**	–0.3406**	0.1381**	–0.0800	0.0521**	–0.3088*	D
'V 327' × 'V 335'	3.1131**	1.0531**	0.2131	–0.1100**	–2.1363**	0.1613*	
'V 327' × 'V 13'	2.4900**	1.0563**	1.5150**	0.5100**	–2.1225**	0.6300**	C
'V 327' × 'V 128'	3.3650**	–0.0188**	1.2725**	0.7100**	–0.0325	–0.3250**	D
'V 327' × 'V 17'	4.5450**	–0.2188**	–1.3050**	–0.2700**	0.5275**	1.0100**	D
'V 335' × 'V 13'	1.8669**	0.0031*	0.8994**	0.0800	-0.0063	–0.4663**	D
'V 335' × 'V 128'	3.0919**	–1.0719**	–1.1506**	–0.0700**	2.0738**	0.7338**	D
'V 335' × 'V 17'	2.9919**	–1.2719**	–1.4131**	0.2300**	2.4938**	1.1588**	D
'V 13' × 'V 128'	2.6688**	–1.0750**	–1.6538**	0.3500**	2.2000**	3.0725**	D
'V 13' × 'V 17'	3.3388**	–1.2750**	–3.5638**	–0.1200**	2.5900**	4.3125**	D
'V 128' × 'V 17'	3.8238**	–0.2000**	0.9663**	0.4700**	0.6900**	–0.2275	D
			Rabi 2000–01				
'CM 128' × 'V 327'	3.2206**	0.0469**	1.5056**	0.2450**	–0.2940**	–1.3140**	D
'CM 128' × 'V 335'	3.2813**	0.9563**	–1.3688**	–0.7250**	–1.8125**	0.9125**	D
'CM 128' × 'V 13'	2.6863**	0.8563**	0.2838**	–0.0300	–1.7125**	–0.1325**	D
'CM 128' × 'V 128'	3.6469**	–0.1469**	0.0469	0.0125	0.1813**	0.1188*	
'CM 128' × 'V 17'	3.7075**	–0.1375**	–0.2525	–0.0575**	0.3375**	0.3950**	
'V 327' × 'V 335'	2.6619**	0.9094**	0.4044*	–0.1525**	–1.8063**	–0.1163	
'V 327' × 'V 13'	2.9744**	0.8094**	0.5419	–0.3650**	–1.4938*	–0.2413	
'V 327' × 'V 128'	3.8325**	–0.1938**	–0.3400	–0.2200**	0.4375**	0.2700**	
'V 327' × 'V 17'	3.5506**	–0.1844**	0.7331**	0.0525*	0.3563**	–0.5099**	D
'V 335' × 'V 13'	1.6850**	–0.1000**	0.3800	0.0150	0.2750**	–0.2400	
'V 335' × 'V 128'	2.6156**	–1.1031**	–0.4469**	0.0875**	2.1688**	0.6313**	D
'V 335' × 'V 17'	2.4913**	–1.0938**	–0.4138	0.2025**	1.9000**	0.5225**	
'V 13' × 'V 128'	2.1081**	–1.0031**	0.6556*	0.6950**	1.7813**	0.1363	
'V 13' × 'V 17'	1.7388**	–0.9938**	1.5413**	1.0550**	1.8625**	–0.4175*	D
'V 128' × 'V 17'	3.7919**	0.0094**	0.0694	0.0050	0.0313	–0.0863	

m, Mean; d, additive; h, dominance; i, additive × additive; j, additive × dominance; l, dominance × dominance; *P= 0.05; ** P=0.01; D denotes duplicate epistasis, C denotes complementary epistasis

sprayed on plants at 5–7 days interval, commencing from 20th day after planting till pre-tasseling stage. The inoculations were preferably done late in the afternoon. The incidence of disease was recorded at dry silk stage following 1.0 to 5.0 rating scale. The ANOVA for variances and components of gene action for disease reaction of 15 crosses during *kharif* 2000 and *rabi* 2000–01 are presented in Tables 1,2 respectively.

During *kharif* 2000, out of 6 susceptible × susceptible crosses, 4 crosses, viz 'CM 128' × 'V 327', 'CM 128' × 'V 128', 'CM 128' × 'V 17' and 'V 327' × 'V 17' exhibited significant negative values for additive (d), dominance (h), and additive × additive (i) components. This indicated that the resistance was controlled by additive and dominance gene action, besides additive × additive type of gene interactions. The negative values indicated resistance, while positive effects reflected susceptibility. These crosses also exhibited opposite values (positive/ negative) for dominance and dominance × dominance interaction, suggesting thereby the presence of duplicate epistasis. The negative and significant 'd', 'i', and 'l' values for the cross 'CM 128' × 'V 17' indicated additive component and, additive × additive and dominance × dominance type of interactions, while cross 'V 327' × 'V 128' exhibited negative and significant additive (d), additive × dominance (j) and dominance × dominance (l) type of gene action. The cross 'V128' × 'V 17' showed significant value for additive component (d) and dominance × dominance (l) type of gene interaction.

Out of 4 crosses involving susceptible × resistant parents, only 1 cross 'CM 128' × 'V 335' showed significant negative 'h', 'i', and 'j' values for dominance, and additive × additive and additive × dominance interactions. The resistance was controlled by dominance (h) and additive × dominance (j) type of interaction in the cross 'CM 128' × 'V 13'. Significant negative additive × additive (i) and additive × dominance (j) interactions indicated duplicate epistasis in cross 'V 327' ×

'V 335'. The cross 'V 327' × 'V 13', showed significant negative value for additive × dominance (j) interaction, indicating complimentary type of epistasis. The resistant × resistant cross 'V 335' × 'V 13' exhibited significant negative additive × dominance ('j') and dominance × dominance ('l') type of gene interactions with duplicate epistasis. Four crosses involving resistant × susceptible parents showed duplicate epistasis. The crosses 'V 335' × 'V 128' and 'V 13' × 'V 17' exhibited significant negative 'd', 'h' and 'i' values indicating additive and dominance gene action and additive × additive interaction. The crosses 'V 335' × 'V 17' and 'V 13' × 'V 128' showed significant negative values for'd' and 'h' indicating that the resistance was largely governed by additive and dominance gene effects.

During *rabi* 2000–01, among 6 susceptible × susceptible crosses, 'CM 128' × 'V 327' exhibited negative significant 'j' and 'l' values indicating additive × dominance and dominance × dominance interactions. Additive component was significant and more pronounced in cross 'CM 128' × 'V 128'. Additive gene effects (d), and all the 3 type of gene interactions were significant in cross 'CM 128' x 'V 17'.

The cross 'V 327' × 'V 128' exhibited significant 'd' and 'i' , 'j' and 'l' values indicating dominance gene effects and all 3 type of gene interactions. Fixable component additive (d) and dominance × dominance (l) were found important in the cross 'V 327' × 'V 17', while 'V 128' × 'V 17' cross exhibited negative value for the dominance × dominance (l) type of gene interaction. Cross 'CM 128' × 'V 335' involving susceptible × resistant parents exhibited significant negative 'h', 'i' and 'j' values suggesting presence of dominance, additive × additive and additive × dominance gene effects. Values for components 'i', 'j' and 'l' in 3 crosses, 'CM 128' × 'V 13', 'V 327' × 'V 335' and 'V 327' × 'V 13' showed additive × additive, additive × dominance and dominance × dominance type of the gene interaction. Duplicate nature of epistasis was noticed for the cross 'CM 128' × 'V 13'. The negative and significant values for the cross 'V 335' × 'V 13' involving resistant parents, indicated dominance (h) gene action and dominance × dominance (l) gene interaction. Among 4 resistant × susceptible crosses, 'V 335' × 'V 128' showed significant negative estimates for 'd' and 'h' indicating both additive and dominance gene effects, while these estimates in cross 'V 335' × 'V 17' were negative but non-significant. The cross 'V 13' × 'V 128' exhibited negative and significant'd' values for additive gene effect, while the cross 'V 13' × 'V 17' showed negative significant'd' and 'l' values for additive and dominance × dominance type of gene effect.

Welz and Geiger (2000) reported partially additive to dominant gene action governing turcicum leaf blight based on generation mean analysis. Ramamoorthy *et al.* (1980) reported primarily additive with partial dominance gene action. Hughes and Hooker (1971) found that additive, dominance and epistatic gene actions were of major importance in all the crosses studied by them. The non-additive effects were generally small and varied in studies conducted by Carson (1995) and Schechert *et al*. (1997).

In the present study additive, dominance as well as epistatic gene actions were also observed to be important in the inheritance of resistance for turcicum leaf blight in most of the crosses. It is therefore suggested that reciprocal recurrent selection may be followed for development of synthetics and hybrids in maize involving early maturing and resistant germplasm. Backcross breeding may be followed if the aim is to transfer resistance.

SUMMARY

Turcicum leaf blight (*Exserohilum turcicum*) is the most common and chronic problem of maize (*Zea mays* L.) causing considerable yield losses. Studies on inheritance of turcicum leaf blight were conducted using 6 generations derived from 4 susceptible 'CM 128', 'V 327', 'V 128' and 'V 17' and 2 resistant inbred lines 'V 335' and 'V 13'. The 6 parents and their 15 F_1's, 15 F_2's, 15 BC_1's and 15 BC_2's, were evaluated for reaction to turcicum leaf blight at 2 locations . The results showed that all types of gene effects, viz additive, dominance and epistasis (additive × additive, additive × dominance and dominance × dominance) were operating in the crosses in governing resistance. It is suggested that population improvement approach, preferably, reciprocal recurrent selection may be followed for exploiting all the 3 types of gene effects in order to develop early maturing, high-yielding and resistant hybrids and synthetics of maize for plains, in general and for hilly areas, in particular.

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