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Evaluation of quality protein maize (QPM) inbred lines and their f₁'s under natural epiphytotic and artificial conditions for turcicum leaf blight [(*Exserohilum turcicum*) (pass.) Leonard and Suggs.]

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Abstract
Maize (*Zea mays* L.), a staple food crop in many parts of the world, is affected by many diseases that reduce yield varies from 28 to 91 percent. A set was obtained by crossing ten QPM inbred lines in 10×10 diallel fashion. In total sixty lines including parents, F₁'s and standard check (HQPM-1, HQPM-4, HQPM-7, PRATAP QPM-1 and VIVEK QPM-9) were evaluated against leaf blight (*Exserohilum turcicum*) of maize under field conditions and artificial conditions during *kharif* 2016 and 2017, respectively. The fourteen cross combination CML163 × CML161, BAJIMQ-08-26 × CML171, CML180 × BAJIMQ-08-26, CML170 × CML161, CML189 × CML162, CML193 × CML163, CML180 × CML163, CML180 × BAJIMQ-08-27, CML180 × CML170, BAJIMQ-08-26 × CML189, CML180 × CML161, CML171 × CML163, CML163 × CML162 and CML189 × CML163 and among the parents CML171 exhibited moderately resistance (MR) for Turcicum leaf blight under natural epiphytotic conditions, whereas only five cross combinations CML170 × CML162, CML193 × BAJIMQ-08-27, CML180 × CML163, CML189 × CML161, CML180 × CML189 and one parent (BAJIMQ-08-26) showed moderately resistance (MR) for turcicum leaf blight under artificial epiphytotic conditions. These lines identified to possess low disease incidence scores against Turcicum leaf blight in the present study could be used successfully in developing genotypes having a desirable level of resistance in disease-endemic areas to aim for sustainable productivity.

Keywords: Artificial, epiphytotic, maize, natural, turcicum leaf blight

Introduction

Maize (*Zea mays* L., 2n=20) belongs to tribe Maydeae, is an important cereal crop of the tropical and sub-tropical regions of the globe and holds an important position in the world's agricultural economy. Maize with a notable productive potential among the cereals, is the third most important grain crop after wheat and rice. At global level maize is cultivated over an area of 197.20 million hectares with an annual production of about 1148.49 million tonnes and average productivity of 5.8 tonnes per hectare (FAOSTAT 2019) [5].

In India, maize contributes to poultry feed (49%), human food (25%), animal feed (12%), industrial use as starch (12%) beverages and seed (1%). Maize in India contributes nearly 9 percent in the national food basket (Pingali and Pandey, 2000) [17]. However, the demand for maize is expected to touch 45mt by 2030 of which 24-25 percent will be used for human consumption, more than 60 percent as poultry and livestock feed and the left over for industrial raw material.

Almost every part of the maize plant is susceptible to numerous diseases that considerably reduce the yield and quality of the crop (Shurtleff, 1980) [21]. Though maize is affected by more than 60 diseases, in India about a dozen are of serious concern. Globally, losses due to maize diseases have been estimated to 22.5 percent (Savary *et al.,* 2019) [20]. For India, a percent loss of 13.2 has been estimated (Payak and Sharma, 1985) [16]. Considering the losses caused by diseases in India, sixteen out of sixty-two diseases have been identified as a major constraint. Maize is one of the most important *kharif* cereal crops and mainly used as food, feed, and fodder in the state and is grown over a wide range of agro-climatic conditions of

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Himachal Pradesh. Diseases are an important constraint for maize production in the state. Among the various diseases of maize, turcicum leaf blight diseases are usually prevalent in different maize growing areas. Caused by *Exserohilum turcicum* is an important foliar disease and widespread in all maize growing areas and considered as a limiting factor for the successful cultivation of maize, and results in yield losses from 28 to 91 percent (Pant *et al*., 2000; Singh *et al*., 2004) [13, 22]. The symptoms first start as small elliptical spots on the leaves as greyish green with water-soaked lesions parallel to leaf margins, the spots turn greenish with age and increase in size, finally attaining a spindle shape with long elliptical greyish or tan lesions. If the disease starts at an early stage, it causes premature death of blighted leaves. As a result, the crop loses their nutritive value as fodder (Payak and Renfro, 1968) [14], have reduced germination capacity, vigor, grain yield, and total sugar content, have restricted starch formation, chaffy kernels, and infected plants are liable to infection with stalk rots (Henry and Kettlewell, 1966) [8]. The fungus has a wide host range and a high pathogenic variability with several races already reported in different parts of the world (Agrios, 2005) [1]. The genetics of resistance is determined in most of the maize genotypes quantitatively and has been used for control of this disease (Sangit *et al*., 2004) [19]. Resistance was partially dominant and controlled by many genes (Vanderplank, 1963) [24]. The disease also affects *rabi* maize in plains. Production and productivity of maize in hilly areas are low as compared to the other areas of the country. Keeping the above points in mind, the present study was carried for identification of resistant sources against TLB disease under artificially inoculated and natural epiphytotic conditions which would be useful further in the improvement of maize populations through population improvement programs.

Material and Methods
The basic materials screened in the present study comprised ten QPM inbred lines. Among ten inbred lines, 8 lines *viz.,* CML161, CML162, CML163, CML170, CML171, CML180, CML189 and CML193 from Indian Institute of Maize Research (IIMR), New Delhi and 2 lines were procured from HAREC Bajaura (Kullu). These lines were crossed in a 10×10 diallel mating system excluding reciprocals during *kharif* 2015. The evaluation for TLB under natural condition was done in the main trial at Experimental Farm of the Department of Crop Improvement, College of Agriculture, CSK HPKV, Palampur situated at 1290.8 m amsl having latitude 32°6' N and longitude 76°3' E during *kharif* 2016 and 2017 and for artificial inoculation evaluation work was carried out at the experimental farm of HAREC Bajaura (Kullu) situated at 31°08' N latitude and 77° E longitude and 1090 m above mean sea level, representing mid-hill, sub-humid zone (Zone 21) of Himachal Pradesh and is endowed with mild summers and cool winters with low monsoon rains (1036.9 mm) having sandy loam soil. For the screening of material against TLB under the artificial conditions, a separate single row trial in RBD with single replications in a plot size of 2.0×0.60 m (1.2 m^2) at a spacing of 60×20 cm was conducted during *kharif* 2016 and 2017. The inoculation was done by dropping a pinch of inoculum by hand inside the whorl of the leaves when the crop was around 35 to 45 days old. This was followed by a spray of water from a knapsack sprayer directed in the whorl. The inoculation was done in the late afternoon. The artificial inoculation was done three times at a weekly interval. Disease reaction of the lines and crosses were recorded for turcicum leaf blight. The data were recorded for leaf blight as per scale used 0-5 (Chenulu and Hora, 1962) [2] Table 1.

Table 1: Scale of disease severity (Chenulu and Hora 1962) [2]

Sr. No.	Score	Disease reaction
1.	0	Highly resistant
2.	1	Resistant
3.	2	Moderately resistant
4.	3	Moderately susceptible
5.	4	Susceptible
6.	5	Highly susceptible

Result and Discussion
Disease score of maize genotypes to *turcicum* leaf blight (TLB) under natural and artificial inoculation under field conditions during *kharif* 2016 and 2017 is given in table 2.

Table 2: Disease score of maize genotypes to *turcicum* leaf blight (TLB) under natural and artificial inoculation under field conditions during *kharif* 2016 and 2017

Sr. No.	Genotypes	TLB (Natural epiphytotic conditions) Palampur		TLB (Artificial inoculation under field conditions) Bajaura	
		2016	2017	2016	2017
1.	CML162 × CML161	3.00	3.00	4.00	4.00
2.	CML163 × CML161	2.00	2.00	3.00	3.00
3.	CML170 × CML161	2.00	2.00	3.00	3.00
4.	CML171 × CML161	3.00	3.00	5.00	5.00
5.	CML189 × CML161	3.00	3.00	2.00	2.00
6.	BAJIMQ-08-26 × CML161	1.50	2.50	2.00	2.00
7.	BAJIMQ-08-27 × CML161	3.00	3.00	4.50	5.00
8.	CML193 × CML161	2.00	2.00	2.00	2.00
9.	CML180 × CML161	1.50	2.50	3.00	3.00
10.	CML163 × CML162	2.00	2.00	4.00	4.00
11.	CML170 × CML162	3.00	3.00	3.00	3.00
12.	CML171 × CML162	3.00	3.00	2.00	2.00
13.	CML189 × CML162	2.00	2.00	3.00	3.00
14.	BAJIMQ-08-26 × CML162	3.00	3.00	3.00	3.00

15.	BAJIMQ-08-27 × CML162	3.00	3.00	5.00	5.00
16.	CML193 × CML162	3.00	3.00	3.00	3.00
17.	CML180 × CML162	3.00	3.00	4.50	3.50
18.	CML170 × CML163	3.00	3.00	3.00	3.00
19.	CML171 × CML163	2.00	2.00	3.00	3.00
20.	CML189 × CML163	2.00	2.00	3.00	3.00
21.	BAJIMQ-08-26 × CML163	2.50	3.50	3.00	3.00
22.	BAJIMQ-08-27 × CML163	3.00	3.00	4.00	4.00
23.	CML193 × CML163	2.00	2.00	3.00	3.00
24.	CML180 × CML163	2.00	2.00	2.00	2.00
25.	CML171 × CML170	3.00	3.00	3.00	3.00
26.	CML189 × CML170	3.00	3.00	4.00	4.00
27.	BAJIMQ-08-26 × CML170	3.50	2.50	5.00	5.00
28.	BAJIMQ-08-27 × CML170	3.00	3.00	3.00	3.00
29.	CML193 × CML170	3.00	3.00	3.00	3.00
30.	CML180 × CML170	2.00	2.00	3.00	3.00
31.	CML189 × CML171	3.00	3.00	3.00	3.00
32.	BAJIMQ-08-26 × CML171	2.00	2.00	4.00	4.00
33.	BAJIMQ-08-27 × CML171	2.00	2.00	2.00	2.00
34.	CML193 × CML171	3.00	3.00	3.00	3.00
35.	CML180 × CML171	3.00	3.00	3.00	3.00
36.	BAJIMQ-08-26 × CML189	2.00	2.00	3.00	3.00
37.	BAJIMQ-08-27 × CML189	3.00	3.00	4.00	4.00
38.	CML193 × CML189	3.00	3.00	3.00	3.00
39.	CML180 × CML189	3.00	3.00	3.00	3.00
40.	BAJIMQ-08-27 × BAJIMQ-08-26	3.00	3.00	3.00	3.00
41.	CML193 × BAJIMQ-08-26	2.50	3.50	3.00	3.00
42.	CML180 × BAJIMQ-08-26	2.00	2.00	3.00	3.00
43.	CML193 × BAJIMQ-08-27	3.00	3.00	2.00	2.00
44.	CML180 × BAJIMQ-08-27	2.00	2.00	3.00	3.00
45.	CML180 × CML193	3.00	3.00	3.00	3.00
46.	HQPM-4	3.00	3.00	3.00	3.00
47.	HQPM-7	3.00	3.00	3.00	3.00
48.	Pratap QPM-1	2.00	2.00	3.50	4.50
49	CML161	3.00	3.00	4.00	4.00
50.	CML162	3.00	3.00	4.00	4.00
51.	CML163	3.00	3.00	3.00	3.00
52.	CML170	3.00	3.00	4.00	4.00
53.	CML171	2.00	2.00	3.00	3.00
54.	CML189	3.00	3.00	4.00	4.00
55.	BAJIMQ-08-26	3.00	3.00	2.00	2.00
56.	BAJIMQ-08-27	3.00	3.00	4.00	4.00
57.	CML193	3.00	3.00	3.00	3.00
58.	CML180	3.00	3.00	3.00	3.00
59.	HQPM-1 (SC-1)	1.50	2.50	4.00	4.00
60.	Vivek QPM-9 (SC-2)	2.00	2.00	4.50	5.00

Disease reaction under natural epiphytotic conditions during *kharif* 2016 and 2017

The present study revealed that among the 60 genotypes, nine parents (CML189, BAJIMQ-08-26, BAJIMQ-08-27, CML193, CML180, CML161, CML162, CML163 and CML170), two QPM Check and 31 F$_1$ hybrids *viz.*, CML162 × CML161, CML170 × CML162, BAJIMQ-08-26 × CML163, CML189 × CML171, CML193 × BAJIMQ-08-26, CML171 × CML162, BAJIMQ-08-27 × CML163, BAJIMQ-08-27 × CML171, CML193 × BAJIMQ-08-27, CML171 × CML161, BAJIMQ-0826 × CML162, CML193 × CML171, CML189 × CML161, BAJIMQ-08-27 × CML162, CML171 × CML170, CML180 × CML171, CML180 × CML193, BAJIMQ-08-26 × CML161, CML193 × CML162, CML180 × CML162, BAJIMQ-08-27 × CML161, BAJIMQ-08-26 × CML170, BAJIMQ-08-27 × CML189, CML193 × CML161, CML170 × CML163, BAJIMQ-08-27 × CML170, CML193 × CML189, CML193 × CML170, CML180 × CML189, CML180 × CML170, BAJIMQ-08-27 × BAJIMQ-08-26 showed the moderately susceptible (MS) reaction. Whereas, one parent (CML171), three QPM Check (PRATAP QPM-1, VIVEK QPM-9, HQPM-1) and 14 cross combination *viz.*, CML163 × CML161, BAJIMQ-08-26 × CML171, CML180 × BAJIMQ-08-26, CML170 × CML161, CML189 × CML162, CML193 × CML163, CML180 × CML163, CML180 × BAJIMQ-08-27, CML180 × CML170, BAJIMQ-08-26 × CML189, CML180 × CML161, CML171 × CML163, CML163 × CML162 and CML189 × CML163 exhibited moderately resistance (MR) for Turcicum Leaf Blight (Table 3) and none of the genotypes showed the susceptible and highly susceptible reaction against turcicum leaf blight during *kharif* 2016 and 2017. Similar results were reported by Kumar and Singh (2002) [11], Garg *et al*. (2007) [6], Kumar and Salgotra (2015) [10] and Thakur *et al*. (2018) [23]. Elliott and Jenkins (1946) screened 200 inbred lines, 126 crosses and 184 double crosses against the Turcicum leaf blight and found that NC34 was the most resistant while CI123, K715, KY114, MO21A, T49B, T105, BK115, CI15 and TX116 showed traces of infection and the resistance to turcicum leaf blight was transmitted to hybrid progeny.

Table 3: Pooled data of reaction of parents and maize hybrids to turcicum leaf blight during *kharif* 2016 and 2017 under natural epiphytotic condition

Disease score	Reaction	Parents and QPM checks	F₁'s
0	HR	-	-
1	R	-	-
2	MR	CML171, PRATAP QPM-1*, VIVEK QPM-9*, HQPM-1*	CML163×CML161, BAJIMQ-08-26×CML171, CML180×BAJIMQ-08-26, CML170×CML161, CML189×CML162,CML193×CML163, CML180×CML163, CML180×BAJIMQ-08-27, CML180×CML170, BAJIMQ-08-26×CML189, CML180×CML161,CML171×CML163, CML163×CML162 and CML189×CML163
3	MS	CML189, BAJIMQ-08-26, BAJIMQ-08-27, CML193, CML180, CML161, CML162, CML163,CML170,HQPM-4*, HQPM-7*	CML162×CML161, CML170×CML162, BAJIMQ-08-26×CML163, CML189×CML1771, CML193×BAJIMQ-08-26, CML171×CML162, BAJIMQ-08-27×CML163, BAJIMQ-08-27×CML171, CML193×BAJIMQ-08-27, CML171×CML161, BAJIMQ-0826×CML162, CML193×CML171, CML189×CML161, BAJIMQ-08-27×CML162, CML171×CML170, CML180×CML171, CML180×CML193,BAJIMQ-08-26×CML161, CML193×CML162, CML180×CML162, BAJIMQ-08-27×CML161, BAJIMQ-08-26×CML170, BAJIMQ-08-27×CML189, CML193×CML161, CML170×CML163, BAJIMQ-08-27×CML170, CML193×CML189, CML193×CML170, CML180×CML189, CML180×CML170, BAJIMQ-08-27×BAJIMQ-08-26
4	S	-	-
5	HS	-	-

*-indicates checks, HR= Highly Resistant, R= Resistant, MR= Moderately Resistant, MS= Moderately Susceptible, S= Susceptible, HS= Highly Susceptible
Note: Scale used 0-5 (Chenulu and Hora 1962) [2].

Disease reaction under artificial epiphytotic conditions during *kharif* 2016 and 2017
Under artificial epiphytotic conditions only one parent (BAJIMQ-08-26) and five F₁'s *viz.*, CML170 × CML162, CML193 × BAJIMQ-08-27, CML180 × CML163, CML189 × CML161 and CML180 × CML189 exhibited moderately resistant (MR) reaction. Whereas, four parents (CML193, CML180, CML171, CML163), two QPM checks (HQPM-7, HQPM-4) and twenty five F₁'s *viz.,* BAJIMQ-08-26 × CML163, CML189 × CML171, CML193 × BAJIMQ-08-26, CML163 × CML161, CML171 × CML162, CML180 × BAJIMQ-08-26, CML170 × CML161, CML189 × CML162, CML193 × CML163, BAJIMQ-0-27 × CML171, BAJIMQ-08-26 × CML162, CML193 × CML171, CML180 × BAJIMQ-08-27, CML171 × CML170, BAJIMQ-08-26 × CML161, CML193 × CML162, CML193 × CML161, CML170 × CML163, BAJIMQ-08-27 × CML170, CML193 × CML189, CML180 × CML161, CML171 × CML163, CML193 × CML170, CML189 × CML163 and CML180 × CML170 showed the moderately susceptible (MS) reaction. Five parents (CML162, CML170, CML189, BAJIMQ-08-27, CML161), two QPM checks (PRATAP QPM-1, HQPM-1) and nine F₁'s *viz,* CML163 × CML162, BAJIMQ-08-27 × CML189, CML162 × CML161, BAJIMQ-08-27 × CML163, BAJIMQ-08-26 × CML171, CML193 × BAJIMQ-08-27, CML189 × CML170, BAJIMQ-08-26 × CML189 and CML180 × CML162 exhibited susceptible (S) reaction. Whereas, one QPM check (VIVEK QPM-9) and six F₁'s *viz.,* BAJIMQ-08-27 × BAJIMQ-08-26, BAJIMQ-08-26 × CML170, BAJIMQ-08-27 × CML161, CML180 × CML171, BAJIMQ-08-27 × CML162 and CML171 × CML161 (Table 4) showed the highly susceptible (HS) reaction for turcicum leaf blight.

Table 4: Reaction of parents and maize hybrids to turcicum leaf blight during *kharif* 2016 and 2017 under artificial epiphytotic condition

Disease score	Reaction	Parents and QPM checks	F₁'s
0	HR	-	-
1	R	-	-
2	MR	BAJIMQ-08-26	CML170×CML162, CML193×BAJIMQ-08-27, CML180×CML163, CML189×CML161, CML180×CML189
3	MS	CML193, CML180, CML171, CML163, HQPM-7*, HQPM-4*	BAJIMQ-08-26×CML163, CML189×CML171, CML193×BAJIMQ-08-26, CML163×CML161, CML171×CML162, CML180×BAJIMQ-08-26, CML170×CML161, CML189×CML162, CML193×CML163, BAJIMQ-0-27×CML171, BAJIMQ-08-26×CML162, CML193×CML171, CML180×BAJIMQ-08-27, CML171×CML170, BAJIMQ-08-26×CML161, CML193×CML162, CML193×CML161, CML170×CML163, BAJIMQ-08-27×CML170, CML193×CML189, CML180×CML161, CML171×CML163, CML193×CML170, CML189×CML163, CML180×CML170
4	S	CML162, CML170, CML189, BAJIMQ-08-27, CML161, HQPM-1*, PARTAP QPM-1*	CML163×CML162, BAJIMQ-08-27×CML189, CML162×CML161, BAJIMQ-08027×CML163, BAJIMQ-08-26×CML171, CML193×BAJIMQ-08-27, CML189×CML170, BAJIMQ-08-26×CML189, CML180×CML162
5	HS	VIVEK QPM-9*	BAJIMQ-08-27×BAJIMQ-08-26, BAJIMQ-08-26×CML170, BAJIMQ-08-27×CML161, CML180×CML171, BAJIMQ-08-27×CML162, CML171×CML161

*-indicates checks, HR= Highly Resistant, R= Resistant, MR= Moderately Resistant, MS= Moderately Susceptible, S= Susceptible, HS= Highly Susceptible
Note: Scale used 0-5 (Chenulu and Hora 1962) [2].

Disease reaction indicating a satisfactory level of disease development and the categorization of genotypes into different classes were appropriate (Table 3 and Table 4). The results are in accordance with Ramdutta and Lal (2005) [18]

who screened maize genotypes under artificial epiphytotic conditions. These findings were in agreement with results obtained by Dharanendra (2003) [3], Ishfaq *et al*. (2014) [9], Mir *et al*. (2015) [12], Gulzar *et al*. (2018) [7], Thakur *et al*. (2018) [23] and Wani *et al*. (2018) [25]. The resistant sources with varying levels of resistance do exist against the Turcicum leaf blight disease of maize. The determination of the genetic basis of the resources and incorporation of their significant difference was observed in disease ratings among the genotypes under field and controlled conditions. The effect of the disease was more severe in the green house plants. The differences attributed due to several factors including controlled environmental conditions, host genotype, inoculation methods and resistance variation among the genotypes.

Continuous efforts to locate resistant source and utilization in resistant breeding programs are imperative to manage the disease in the long run. Some genotypes possess low disease incidence scores against turcicum leaf blight (TLB) in the present study could be used successfully in developing genotypes having the desired level of resistance in disease-endemic areas to aim for sustainable productivity. The lines identified to possess less proneness to turcicum leaf blight in the present study can be used successfully in developing high yielding early maturing varieties for the hill region having a high level of resistance to turcicum leaf blight. However resistance and susceptibility to the disease may be attributed to anatomical structures of studied genotypes, however, it needs further investigations.

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