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Evaluation of Inbred Lines and Development of Turcicum Leaf Blight Resistant Single Cross Maize Hybrids

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Turcicum leaf blight (TLB) is the most important disease of maize growing areas of India. To identify new resistance sources and establish durability of known resistance sources, 30 maize inbred lines were evaluated against TLB under artificial inoculation during *kharif* 2013 and *kharif* 2014. Ten inbred lines were found resistant against TLB. Based on *per se* performance and resistance to TLB nine inbred lines *viz.*, DMIT 105, DMIT 106, DMIT 111, DMIT 113, DMIT 118, DMIT 121, DMIT 123, DMIT 124 and DMIT 125 were used to develop 36 single cross hybrids and were screened to identify resistant hybrids. Thirty two hybrids were found resistant with disease score 1 and 2. Based on percent disease index (PDI) and area under disease progress curve (AUDPC) values, the components of blighting, inbred lines *viz.,* DMIT 105, DMIT 113, DMIT 118 and DMIT 126 and hybrids *viz.,* DMIT 105 × DMIT 125, DMIT 106 × DMIT 111, DMIT 106 × DMIT 121, DMIT 106 × DMIT 125, DMIT 111 × DMIT 113, DMIT 111 × DMIT 121, DMIT 113 × DMIT 118, DMIT 113 × DMIT 121, DMIT 113 × DMIT 125, DMIT 118 × DMIT 121, DMIT 118 × DMIT 124 and DMIT 121 × DMIT 123 were identified as slow blighters. These hybrids should be involved in the crop improvement programmes.

Keywords: Hybrids, Inbred lines, Maize, PDI, Turcicum leaf blight.

Maize (*Zea mays* L.) is one of the world's three most important cereal crops along with rice and wheat. India is rich in maize germplasm particularly of tropical and subtropical types with maximum variability and adaptability. Due to moderate low temperature and high humidity during the maize growing period, turcicum leaf blight of maize (syn. Northern leaf blight) caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs is recurrent problem in most maize growing regions of India. Most of the cultivated genotypes are more or less susceptible to this disease and the loss in yield has been reported to vary from 28 to 91 per cent (Harlapur *et al.,* 2000). Various options are available to control maize leaf blight such as the use of host plant resistance, cultural practices and fungicides. Host plant resistance is the cheapest and most effective way to control leaf blight disease because chemical treatments are expensive and often ineffective.

Slow blighting is a form of resistance, where despite a susceptible host reaction, the rate of disease development is very slow. Slow blighting is expressed in the reduced infection of a plant by a blight fungus, late appearance of blight in the life cycle of the host and retarded development of the fungus. Partial resistance is a form of incomplete resistance, characterized by a reduced rate of epidemic development (Parlevliet,

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1979). The phenomenon of slow blighting was observed in Helminthosporium leaf blight of wheat (Patil, 2000) and partial resistance to TLB of maize (Mallikarjuna, 1998). The utilization of resistance source in breeding programme requires detailed information on various components of resistance under field conditions. Hence a field study was undertaken to determine the turcicum leaf blight response of 30 maize inbred lines to development of resistant single cross maize hybrids and to evaluate the resultant hybrids against TLB to identify resistant hybrids and blighting reaction.

MATERIALS AND METHODS

The experiments were conducted at Main Agricultural Research Station, maize Scheme, University of Agricultural Sciences, Dharwad, Karnataka (15° 25' N latitude, 70° 25' East longitude) with an altitude of 678 m above mean sea level. Each test line was sown in 2 rows of 4 m length and rows were spaced at 60 cm in randomized block design with two replications. The test genotypes were inoculated with *E. turcicum* multiplied on sorghum grain culture by whorl drop method. Inoculation was done twice at 35 and 45 days after sowing (DAS) followed by water spray so as to maintain required humidity for successful infection. Spreader rows of highly susceptible inbred CM 202 were planted at the border and at regular interval as a source of secondary inoculum for disease development. Observations on blight severity was recorded at the time of tasselling, 20 days after tasselling and at maturity using 1-5 scale (Payak and Sharma, 1983). Based on this scale, the genotypes were classified into three groups *viz.*, resistant (disease score ≤2), moderately resistant (disease score 3) and susceptible (disease score >4). Further, PDI (Wheeler, 1969) and AUDPC (Wilcoxson *et al.,* 1975) were calculated by using the following formula.

$$PDI = \frac{\text{Sum of individual disease ratings}}{\text{Total No. of plants observed} \times \text{Maximum disease grade}} \times 100$$

$$\text{AUDPC, } A = \sum_{i=1}^{k} 1/2\,((S_i+S_{i-1})\,(T_i - T_1))$$

Where,
K= Number of successive observations
S_i = Severity of disease at i^{th} period
S_{i-1} = Severity of disease proceeding to i^{th} period
$T_i - T_1$ = time intervals between two observations

Screening of inbred lines

The experimental materials in the study composed of sixty inbred lines developed at Main Agricultural Research Station (MARS), maize Scheme, University of Agricultural Sciences, Dharwad and forty inbred lines received from Indian Institute of Maize Research, New Delhi. From one hundred lines, thirty resistant lines were selected based on disease reaction and *per se* performance during *kharif*-2013 and were selfed. These lines along with susceptible check (CM 202) were again grown during *kharif*-2014 under artificial epiphytotic condition to identify new sources of resistance against TLB. The list of selected resistant inbred lines and their pedigree are presented in Table 1.

Evaluation of hybrids

Among thirty six inbred lines evaluated, nine resistant (disease score ≤ 2) and good *per se* performance inbred lines *viz.*, DMIT 105, DMIT 106, DMIT 111, DMIT 113, DMIT 118, DMIT 121, DMIT 123, DMIT 124 and DMIT 125 were selected for the production of single crosses. A total of 36 hybrids were produced in half diallel fashion during summer- 2014-15 and were screened for TLB under artificial epiphytotic condition during *kharif* 2015.

RESULT AND DISCUSSION

The inbred lines and hybrids of maize in present investigation were evaluated under artificial epiphytotic conditions during *kharif* 2014 and *kharif* 2015 to identify resistance source and to develop resistant maize hybrids against turcicum leaf blight (*Helminthosporium turcicum*).

Screening of inbred lines

Out of thirty inbred lines, ten lines *viz.,* DMIT 105, DMIT 106, DMIT 111, DMIT 113, DMIT 118, DMIT 121, DMIT 123, DMIT 124, DMIT 125 and DMIT 126 recorded less than or equal to score 2 and grouped them as resistant; twelve inbred lines *viz.,* DMIT 101, DMIT 103, DMIT 104, DMIT 107, DMIT 108, DMIT 109, DMIT 110, DMIT 112, DMIT 119, DMIT 122, DMIT 127 and DMIT 129 possessing score 3.0 were categorized as moderate resistant and eight inbred lines *viz.,* DMIT 102, DMIT 114, DMIT 117, DMIT 120, DMIT 130, DMIT 115, DMIT 116 and DMIT 128 exhibited TLB score 4 were categorized as susceptible and susceptible check (CM202) had score 5 was categorized as highly susceptible to TLB (Table 2). These are in agreement with results obtained by earlier workers (Chandrashekara *et al.,* 2014 and Singh *et al.* 2014) while working with turcicum leaf blight of maize.

Evaluation of hybrids

The disease score at maturity ranged from 1 to 3 in hybrids and resistant check compared to susceptible check (score 5). Out of 36 hybrids, fourteen hybrids possessed a disease score of 1 which were found to be highly resistant. Eighteen hybrids scored disease score of 2 indicating that they were resistant to the disease while, remaining four hybrids recorded disease score 3, which were found to be moderately resistant to the disease (Table 3). Similar results were reported by Kumar and Salgotra (2015).

Table 1. List of inbred lines along with their pedigrees

No.	Line No	Pedigree/source population
1	DMIT101	WNCDMR 19 RYDWS 1592
2	DMIT 102	DMH 8255-6-8-4-48
3	DMIT 103	900 Gold × NE 1412004-X-X-X-13
4	DMIT 104	900 Gold × NE 1412004-X-X-X-20
5	DMIT105	WNCDMR6RYFWS 8008
6	DMIT 106	NK 6240 × K-155-X-X-X-18
7	DMIT 107	BIO 6891-16-5-6
8	DMIT108	SOS1YQBB26-B
9	DMIT 109	CM 215 × CM 145-1-5-8-28
10	DMIT 110	NK 6240 × K-128-X-X-X-15
11	DMIT 111	NK 6240 × K-128-X-X-X-18
12	DMIT 112	CML 332 × CML 325-6-5-25
13	DMIT 113	PINNACLE × K148-X-X -X-X-X-16
14	DMIT 114	30V92 × K148-X-X-X-15
15	DMIT 115	NK 6240 × K-132-X-X-X-11
16	DMIT 116	KS × 4901 -X-X-X-X-14
17	DMIT 117	NK 6240 × CML 162-3-5-9-8
18	DMIT 118	D 9081-6-4-8-20
19	DMIT 119	900 GOLD × NE1412004-X-X-X-X-20
20	DMIT 120	CML146/CML176-B-29-1-3
21	DMIT 121	NK 6240 × CML 412-6-5-20
22	DMIT 122	WNCDMR11R 4788
23	DMIT 123	CM 290 × CML 160-X-X-X-3
24	DMIT124	WNCDMR19RYDWS 1396
25	DMIT125	WNCDMR6RYFWS 8053
26	DMIT126	WNCDMR19RYDWS 1712A
27	DMIT 127	VA-6-9-66
28	DMIT128	WNCDMR6RYFWS 8105
29	DMIT 129	WNCDMR11R6362
30	DMIT 130	WNCDWR10RYFWS 8627

Per cent disease index (PDI)

Significant differences in disease severity were observed among the inbred lines and hybrids between days to tasselling and at maturity. The difference of genotypes in disease severity was due to diversity in their genetic makeup as reported by Williams and Hallauer (2000) and Kraja *et al.* (2000). Per cent disease index (PDI) and area under disease progress curve (AUDPC), the components of blighting, were calculated to identify slow blighting genotypes.

Per cent disease index shows the cumulative value of disease in the target genotypes. Its value is based on disease severity. Four inbred lines *viz.,* DMIT 105, DMIT 113, DMIT 118 and DMIT 126, fifteen hybrids which were developed from resistant inbreds *viz.,* DMIT 106 × DMIT 111, DMIT 106 × DMIT 121, DMIT 106 × DMIT 125, DMIT 111 × DMIT 113, DMIT 111 × DMIT 118, DMIT 111 × DMIT 121, DMIT 111 × DMIT 124, DMIT 113 × DMIT 118, DMIT 113 × DMIT 121, DMIT 113 × DMIT 125, DMIT 118 × DMIT 121, DMIT 118 × DMIT 123, DMIT 118 × DMIT 124, DMIT 118 × DMIT 125 and DMIT 121 × DMIT 123 and resistant check P 3051 showed not only delayed onset of the disease but also ended up with significantly lower disease severity (Table 4 and 5). In these genotypes, blight development was more or less the same during different periods of observation. Result indicates the resistance is oligogenic or polygenic with partial and race-nonspecific resistance. Hossain (1987) reported that maize genotypes Thaltzapam-8146 was found partially resistant to TLB. Sharma and Payak (1990) recorded durable resistance in two maize inbred lines CM-104 and CM-105 against *Exserohilum turcicum* and observed that these inbred lines were potential in transmitting resistance in hybrid combinations through additive gene action. Durability of their resistance was associated with polygenic control.

Area Under Disease Progress Curve (AUDPC)

The AUDPC estimates the area under the actual infection curve. It is expressed as accumulation of daily percent infection values and interpreted directly without transformation. The higher the AUDPC, the more susceptible is the clone or variety. The AUDPC is calculated from all the three ratings at different time thus leading to a more accurate phenotypic evaluation. The loss of active leaf area results in less photosynthetic available region during the grain filling stage which eventually results in producing smaller kernels. This reduction may eventually contribute to the overall yield losses.

Area under disease progress curve was calculated for inbred lines, 36 hybrids and resistant and susceptible checks and it is presented in Table 4 and 5. The AUDPC values differed considerably for genotypes. The lowest AUDPC values were noticed in five inbred lines *viz.,* DMIT 105 (424.47), DMIT 113 (427.03), DMIT 118 (366.65), DMIT 121 (493.64) and DMIT 126 (387.62). Among hybrids and checks, twelve hybrids *viz.,* DMIT 105 × DMIT 125 (399.10), DMIT 106 × DMIT 111 (292.74), DMIT 106 × DMIT 121 (185.46), DMIT 106 × DMIT 125 (379.34), DMIT 111 × DMIT 113 (333.75), DMIT 111 × DMIT 121 (285.69), DMIT 113 × DMIT 118 (173.59), DMIT 113 × DMIT 121 (193.19), DMIT 113 × DMIT 125 (143.66), DMIT 118 × DMIT 121 (245.52), DMIT 118 × DMIT 124 (300.10) and DMIT 121 × DMIT 123 (289.25) and resistant check P 3051 (364.35) showed low AUDPC values. The high AUDPC values among hybrids were observed in the hybrid DMIT 113 × DMIT 123 (823.75) and in susceptible check CM 202 (2442.93). This is in accordance with the work of earlier reports (Mallikarjuna, 1998). In general, AUDPC values took care of initial and terminal severity and also rate of infection. Hence, genotypes with lower AUDPC values can

Table 2. Categorization of maize inbred lines based on the reaction to *E. turcicum* under artificial epiphytotic condition.

Reaction	Score	Inbred lines
Resistant	≤ 2	DMIT105, DMIT106, DMIT111, DMIT113, DMIT118, DMIT121, DMIT123, DMIT124, DMIT125, DMIT126
Moderately resistant	3	DMIT101, DMIT103, DMIT104, DMIT107, DMIT108, DMIT109, DMIT110, DMIT112, DMIT119, DMIT122, DMIT127, DMIT129
Susceptible	4	DMIT102, DMIT114, DMIT117, DMIT120, DMIT130, DMIT115, DMIT116, DMIT128, DMIT135
Highly susceptible	5	DMIT131, DMIT132, DMIT133, DMIT134, DMIT136

Table 3. Categorization of maize hybrids based on the reaction to *E. turcicum* under artificial epiphytotic condition

Reaction	Score	Hybrids
Highly resistant	1	DMIT106×DMIT121,DMIT106×DMIT125, DMIT111×DMIT113, DMIT111×DMIT118, DMIT111×DMIT121, DMIT111×DMIT124, DMIT113×DMIT118, DMIT113×DMIT121, DMIT113×DMIT125, DMIT118×DMIT121, DMIT118×DMIT123, DMIT118×DMIT124, DMIT118×DMIT125, DMIT121×DMIT123
Resistant	2	DMIT105×DMIT111, DMIT105×DMIT113, DMIT105×DMIT121, DMIT105×DMIT124, DMIT105×DMIT125, DMIT106×DMIT111, DMIT106×DMIT113, DMIT106×DMIT118, DMIT106×DMIT123, DMIT106×DMIT124, DMIT111×DMIT123, DMIT111×DMIT125, DMIT113×DMIT124, DMIT121×DMIT124, DMIT121×DMIT125, DMIT123×DMIT124, DMIT123×DMIT125, DMIT124×DMIT125
Moderately resistant	3	DMIT105×DMIT106, DMIT105×DMIT118, DMIT105×DMIT123, DMIT113×DMIT123

be considered as slow blighters. It indicated that such genotypes were more tolerant to pathogen without any economic damage.

Based on the results of the present study, it is concluded that the inbred lines *viz.,* DMIT 105, DMIT 113, DMIT 118, DMIT 121 and DMIT 126 categorized as highly resistant and resistant can be well utilized successfully for developing hybrids and composites in future breeding programme.

In the cross combinations, the hybrids with disease score less than 2 for turcicum leaf blight along with desirable specific combining ability for grain yield and its component traits appear to be suitable for cultivation in blight predominant areas. In the present study, it is observed that the inbred lines *viz.,* DMIT 105, DMIT 113, DMIT 118, DMIT 121 and DMIT 126 and hybrids *viz.,* DMIT 105 × DMIT 125, DMIT 106 × DMIT 111, DMIT 106 × DMIT 121, DMIT 106 × DMIT 125, DMIT 111 × DMIT 113, DMIT 111 × DMIT 121, DMIT 113 × DMIT 118, DMIT 113 × DMIT 121, DMIT 113 × DMIT 125, DMIT 118 × DMIT 121, DMIT 118 ×

Table 4. Per cent disease index (%) and area under disease progress curve of turcicum leaf blight in inbred lines of maize

Inbred line	PDI at tasselling	PDI at 20 days after tasselling	PDI at maturity	AUDPC
DMIT101	6.54	21.84	24.50	812.64
DMIT102	7.00	14.56	26.17	692.86
DMIT103	7.88	20.25	25.84	820.87
DMIT104	9.35	22.33	34.78	981.44
DMIT105	3.65	10.28	14.58	424.47
DMIT106	8.83	13.83	18.99	643.24
DMIT107	9.64	19.08	30.19	876.31
DMIT108	12.48	25.37	33.90	1095.9
DMIT109	8.18	19.00	25.73	800.98
DMIT110	10.43	22.69	28.96	951.99
DMIT111	7.48	16.08	22.37	694.94
DMIT112	14.69	27.15	36.63	1202.97
DMIT113	4.42	8.97	15.94	427.03
DMIT114	13.82	27.72	37.41	1204.81
DMIT115	16.43	30.05	41.49	1344.41
DMIT116	10.85	20.36	31.92	943.46
DMIT117	14.31	26.84	36.09	1183.75
DMIT118	2.95	8.06	14.66	366.65
DMIT119	5.51	22.50	27.10	831.26
DMIT120	14.42	29.01	51.27	1381.17
DMIT121	6.54	10.00	16.30	493.64
DMIT122	13.92	23.03	37.89	1117.82
DMIT123	8.48	12.99	18.81	617.42
DMIT124	8.45	13.32	21.44	649.75
DMIT125	7.09	15.49	19.27	644.32
DMIT126	3.03	9.26	14.18	387.62
DMIT127	17.34	23.13	28.88	1098.17
DMIT128	22.08	31.13	36.64	1430.55
DMIT129	14.27	25.53	40.35	1199.55
DMIT130	15.64	27.00	41.18	1264.73
CM 202 (Check)	31.75	51.27	82.32	2483.56
CV	9.07	12.76	7.15	
CD@5%	2.02	5.45	4.41	
CD@1%	2.71	7.33	5.93	

DMIT 124 and DMIT 121 × DMIT 123 possessed slow blighting characters. Thus, the slow blight resistant character is very important and can be used in selection process for developing the hybrid or used as such for cultivation. If slow blighting genotypes are widely used in a disease control strategy, the rate of leaf blight development will not only be reduced during the rainy season, but also during the subsequent *rabi* / summer seasons when the resistance of slow blighting genotype in adult plant stage of growth is operating. Therefore, deployment of the identified slow turcicum leaf blighting genotypes could be an important TLB management strategy in maize.

Table 4. Per cent disease index (%) and area under disease progress curve of turcicum leaf blight in maize hybrids

Hybrid	PDI at tasselling	PDI at 20 days after tasselling	PDI at maturity	AUDPC
DMIT105×DMIT106	3.09	9.53	20.88	461.23
DMIT105×DMIT111	4.09	12.37	20.37	532.70
DMIT105×DMIT113	1.23	9.79	19.74	417.77
DMIT105×DMIT118	9.19	17.17	27.34	800.62
DMIT105×DMIT121	4.03	9.12	17.22	435.29
DMIT105×DMIT123	8.92	17.82	27.59	810.70
DMIT105×DMIT124	3.03	11.75	20.89	504.56
DMIT105×DMIT125	4.28	8.08	15.18	399.10
DMIT106×DMIT111	2.33	6.25	12.13	292.74
DMIT106×DMIT113	5.26	10.70	19.69	516.09
DMIT106×DMIT118	3.06	7.97	18.93	409.97
DMIT106×DMIT121	0.32	3.79	10.32	185.46
DMIT106×DMIT123	0.32	9.56	20.94	407.04
DMIT106×DMIT124	3.70	7.85	18.57	416.78
DMIT106×DMIT125	3.71	8.56	13.39	379.34
DMIT111×DMIT113	4.72	5.54	12.86	333.75
DMIT111×DMIT118	7.23	7.38	12.23	414.55
DMIT111×DMIT121	1.65	6.66	11.94	285.69
DMIT111×DMIT123	6.38	11.05	20.67	555.26
DMIT111×DMIT124	7.12	8.63	11.97	434.68
DMIT111×DMIT125	4.49	9.27	18.08	456.04
DMIT113×DMIT118	0.32	4.21	8.29	173.59
DMIT113×DMIT121	0.32	4.67	9.33	193.19
DMIT113×DMIT123	9.90	17.62	27.33	823.75
DMIT113×DMIT124	7.18	12.40	21.53	606.71
DMIT113×DMIT125	0.32	2.59	8.55	143.66
DMIT118×DMIT121	0.32	6.69	10.53	245.52
DMIT118×DMIT123	5.92	9.48	14.35	451.39
DMIT118×DMIT124	1.62	7.24	12.29	300.10
DMIT118×DMIT125	7.43	7.70	13.17	434.32
DMIT121×DMIT123	1.23	7.02	12.42	289.25
DMIT121×DMIT124	7.54	12.87	22.76	635.76
DMIT121×DMIT125	5.86	11.48	20.09	547.82
DMIT123×DMIT124	7.52	14.72	24.01	684.82
DMIT123×DMIT125	4.27	13.80	23.02	591.38
DMIT124×DMIT125	8.00	14.63	22.56	678.17
P3051 (Resistant check)	4.16	7.92	12.28	364.35
CM 202 (Susceptible check)	28.87	54.43	77.68	2442.93

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