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Research Article

Evaluation of finger millet genotypes for partial resistance to leaf blast caused by *Pyricularia grisea*

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Abstract
Blast of finger millet (ragi) caused by *Pyricularia grisea* is disastrous disease to limit the potential yield levels in the farmers field. The pathogen affects the crop at all growth stages and the most susceptible stage for leaf blast is seedling stage. Use of resistant cultivars for minimizing losses due to leaf blast at early stage of crop growth is a viable and economical alternative. In the present study, partial resistance to leaf blast in fourteen genotypes of finger millet was assessed under field conditions. None of the genotypes were highly resistant to leaf blast. However, two genotypes namely PR 10-30 and VL 368 were shown resistance. Seven genotypes namely VR 988, VL 353, VL 348, TNAU 1214, GPU 45, VL 369, KOPM 942 were found moderately resistant, three namely PPR 2773, KRI 007-01, VR 708 were susceptible and two namely TNAU 1226 and REC 69 were highly susceptible. The correlation coefficients between leaf blast severities (LBS) with different components of partial resistance of slow blasting were significant. Low value of coefficient of infection (CI), apparent infection rate (r), area under disease progress curve (AUDPC), lesion number (LN), lesion area (LA), lesion circumference (LC) and high value of incubation period (IP) were recorded in resistant genotypes of finger millet, whereas, higher values of CI, r, AUDPC, LN, LA, LC and low values of IP were recorded in highly susceptible genotypes. A significant positive correlation was found in leaf blast severity with CI (r=0.948*), r (r=0.829*), AUDPC (r=0.998*), LN (r=0.967*), LA (r=0.957*), LC (r=0.976*) whereas IP (r=-0.825*) was negatively correlated with blast resistance. PR 10-30 and VL 368 showed higher degree of partial resistance or slow blasting resistance against *P. grisea* infection on finger millet.

Key words
Finger millet, leaf blast, *Pyricularia grisea*, partial resistance, correlation

Introduction

Finger millet (*Eleusine coracana*) commonly known as ragi is a highly nutritious small seeded cereal crop cultivated by poor people for food in rainfed as well as irrigated conditions. In India, the crop is cultivated in 1.6 m ha area with a production of about 1.59 m t and productivity of 1428 kg ha^{-1} (Anon., 2013) and is an important component of dry land agriculture. The grains are rich source of protein, fiber, minerals and amino acids, which are crucial to human health and growth. Blast caused by *Pyricularia grisea* [Teleomorph: *Magnaporthe grisea*] is an important disastrous disease of finger millet occurs at all the stages of crop growth. Seedling stage is reported most vulnerable for leaf blast infection and severe infection in nursery may damage the whole plant of finger millet (Nagaraja *et al.*, 2007). Under naturally existing disease conditions, 4.44 per cent loss in grain yield of finger millet due to leaf blast was reported by Bisht *et al.* (1985). Host resistance is the most desirable means of managing blast. Partial resistance is race non- specific, polygenic and durable in some cultivars and has been described as slow blasting resistance (Parlevliet, 1979). Mechanism of blast resistance in finger millet has been reported (Jain and Yadava, 2004) but literature on slow blasting resistance or partial resistance in finger millet to *P. grisea* is meager. Therefore, in the present study, different components of partial resistance in relation to leaf blast were studied in fourteen genotypes of finger millet under field conditions.

Materials and methods

Fourteen finger millet cultivars comprising pre-released and released genotypes were screened against leaf blast under artificial inoculations at experimental area of agriculture college, Rewa (M.P.). The seeds of test genotypes were sown in two rows of 3.0 m length plot with 22.5 cm row to row and 10.0 cm plant to plant spacing in RBD with three replications during *kharif* 2013. One row of susceptible cultivar REC 70 was sown after each test entry to create artificial epiphytotics of the disease. Recommended package of practices were followed for optimum crop growth. Spore suspension of *Pyricularia grisea* was prepared by immersing chopped blast infected leaves @ 1 g leaf into 30 ml distilled water and sprayed during the seedling stage at evening hours. Leaf blast severity was recorded at seedling stage adopting 0-5 grade scale. The data recorded on percent necrotic leaf area were angular transformed before statistical analysis. The Finger millet genotypes were grouped into different categories of resistance and susceptibility to leaf blast. Lesion length (mm), lesion width (mm) was recorded in middle leaves of finger millet genotypes and lesion area (mm^2) was calculated. Lesion circumference expressed in mm was calculated in leaf blast lesions adopting formula given by Leontine *et al.* (1995).

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Lesion circumference (LC) = ½*3.14* lesion length + lesion width

Different component characters namely coefficient of infection, incubation period, apparent infection rate, area under disease progress curve were recorded and used as criteria in the present study to identify finger millet genotypes with slow blasting or partial resistance under field conditions. Coefficient of infection (CI) was calculated for 14 cultivars of finger millet by multiplying disease severity (DS) and constant values of infection type (IT). The constant values of infection types were used based on Resistant (R) = 0.1; Moderately resistant (MR) = 0.25 ; Moderately susceptible (MS) = 0.5 ; Susceptible (S) = 0.75 and Highly susceptible (HS) = 1.0 (Pathan and Park, 2006). The incubation period (IP) is the time elapsed between inoculation and first disease symptom appearance. Incubation period in hours was recorded in 14 cultivars of finger millet for leaf blast. Sequential apparent infection rate (r) was estimated in terms of disease severity on finger millet genotypes at different intervals for leaf blast by following the formula given by Van der Plank (1963).

$$r = 1/t_2\text{-}t_1 \,(\log_e X_2/ 1\text{-} X_2) - (\log_e X_1/ 1\text{-} X_1)$$

where, r = Apparent infection rate, X_1 and X_2 are the amounts of the disease recorded and t_1 and t_2 are the corresponding time period.

The area under disease progress curve (AUDPC) was computed for leaf blast using per cent necrotic leaf area following a simple midpoint (trapezoidal) rule as described by Madden *et al* (2007).

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left(\frac{y_i + y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

where "t" is time in days of each reading, "y" is the percentage of affected foliage at each reading and "n" is the number of readings.

Correlation coefficients among leaf blast infections and component characters of partial or slow blasting resistance in 14 cultivars of finger millet were calculated as per standard procedure.

Results and discussion

Severity of leaf blast ranged from 4.7 to 55.0 % (2 to 5 score grades) in 14 cultivars of finger millet (Table 1) and data revealed that two cultivars namely PR 10-30 and VL 368 were shown resistance against leaf blast. Seven cultivars namely VR 988, VL 352, VL 348, TNAU 1214, GPU 45, VL 369 and KOPN 942 were moderately resistant, whereas three cultivars namely PPR 2773, KRI 007-01, VR 708 were susceptible. Two cultivars namely TNAU 1226 and REC 69 were found highly susceptible to leaf blast under artificial inoculations. Earlier, GPU 45 was also reported resistant to leaf blast (Anon., 2013), Coefficient of infection (CI) was ranged from 0.47 to 55.0 and incubation period (IP) was ranged from 52.3 to 96.8 hrs. Resistant genotype namely, PR 10-30 and VL 368 exhibited lowest leaf blast severity and coefficient of infection; where as in susceptible and highly susceptible genotypes, leaf blast severity and coefficient of infection were high. Lower incubation period *i.e*. 52.3, 55.0, 55.6 and 59.9 hours were recorded in susceptible genotypes of finger millet, whereas higher incubation period was recorded in resistant (PR 10- 30 , VL 368) and moderately resistant (VR 988 , VL 352 , VL 348 , TNAU 1214 , GPU45, VL 369 and KOPN 942) genotypes of finger millet. It indicates that symptoms appears early in susceptible to highly susceptible genotypes as compared to moderately resistant to resistant genotypes after inoculation with blast causing pathogen.

Periodic development of leaf blast incidence on the basis of necrotic leaf area (%) and number of spot / leaf in 14 genotypes of finger millet are presented in table 2**.** Significant variations in percent necrotic area and number of spots per leaf were recorded. The data revealed that increase in percent necrotic leaf area from 45 days after sowing (DAS) to 64 days after sowing (DAS) was comparatively low in resistant genotypes PR 10-30 (3.9 to 4.9 %) and VL 368 (3.2 to 4.7 %). In seven moderately resistant genotypes, the increase in percent necrotic leaf area was 6.4 to 23.3 %, where as in susceptible genotypes it was 7.3 to 50.0 % and 14.3 to 55.0 % in highly susceptible genotypes. Average number of spots in 14 finger millet genotypes was ranged 0.8 to 4.9 in 45 days after sowing (DAS), 0.9 to 7.7 in 51 days after sowing (DAS), 1.9 to 9.9 in 57 days after sowing (DAS) and 2.7 to 12.6 in 64 days after sowing (DAS). Average number of spots per leaf was 2.7 to 3.0 in resistant, 3.4 to 4.8 in moderately resistant, 4.5 to 11.4 in susceptible and 10.8 to 12.6 in highly susceptible genotypes of finger millet. The lesion number and necrotic zone area were identified as the most important genetic and heritable components for indirect selection of slow blasting resistance in rice (Mukherjee and Nayak, 1997).

Apparent infection rate (r) calculated on the basis of percent necrotic leaf area and computed values for area under disease progress curve (AUDPC) in 14 genotypes of finger millet are presented in table 3. Average infection rate between 45 to 51 DAS, 51 to 57 DAS and 57 to 64 DAS were 0.076, 0.097 and 0.032 per cent per day, respectively, which was highest between 51 to 57 DAS. It indicated that environmental conditions were more congenial for leaf blast incidence between 51 to 57 DAS. Average infection rate (r) ranging from 0.013 to 0.102 percent per day was minimum in PR 10-30 followed by VL 368 (0.022), VL 248 (0.040) and VL 369 (0.058) whereas, maximum 'r' value was

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recorded in TNAU 1226 followed by REC 69 (0.097), KRI 007-01 and PPR 2773 (0.092), which shows susceptibility against leaf blast. Values of AUDPC were calculated using periodic leaf blast severity observations and it varied from 67.5 to 644.1 with a mean of 337.6. The AUDPC values were recorded as 67.5 to 78.6 in resistant, 211.2 to 287.7 in moderately resistant, 294 to 598.2 in susceptible and 581.7 to 644.1 in highly susceptible genotypes. Values of AUDPC increases with the increase in degree of leaf blast severity in finger millet. Lower estimated AUDPC values in resistant genotypes indicate the slower and restricted progress of leaf blast development.

Growth rate of finger millet blast varied from 0.03 to 0.16 unit per days was reported by Bisht and Shrivastava (1991). Determination of area under disease progress curve is reported as an indication of slow blasting and fast blasting trait of the finger millet cultivar against blast in finger millet by Kumar and Krishnamurthy (2008).

Lesion length, lesion width and lesion area ranging from 4.9 to 16.3 mm,1.1 to 3.7 mm and 5.47 to 44.87 mm^2 , respectively were recorded (Table 4). In resistant genotypes, lesion length, varied from 4.9 to 5.3 mm, lesion width was 1.5 to 1.7 mm and leaf area was 5.47 to 6.70 mm^2, where as in highly susceptible genotypes lesion length was ranged from 13.1 to 16.3 mm, lesion width was 3.5 to 3.7 mm and leaf area was 34.11 to 44.87 mm^2. Lesion size was more in susceptible to highly susceptible genotypes compared to resistant and moderately resistant genotypes. It indicate that development of pathogenic propagule in tissue of resistant cultivars is confined to restrict area as compared to highly susceptible cultivars and contributes to slow blasting or partial resistance in finger millet against leaf blast. Shorter lesion area and lesion cover were reported in slow blasting resistant genotypes of rice by Mukherjee *et al.,* (2013) and Waghunde *et al.,* (2013). These reports are in agreement with the present findings. Similarly, significant differences in development and enlargement of lesions were reported in different genotypes of finger millet possessing various degree of resistance (Sunil and Anilkumar, 2003).

Lesion circumference (LC) in 14 finger millet genotypes was (Table 4) ranged between 10.06 to 31.33 with a mean of 17.99 mm. Maximum LC was recorded in REC 69 followed by KRI 007-01 (28.87 mm), PPR 2773 (27.23 mm) and TNAU1226 (26.13 mm), which are susceptible to highly susceptible for leaf blast. Minimum LC was recorded in VL 368 (10.06 mm) followed by PR 10-30 (10.97 mm). Both the genotypes were resistant to leaf blast.

The estimates of correlation coefficients (r) among leaf blast severity and components characters of slow blasting resistance are presented in table 5. The leaf blast severity (LBS) was found to be positively correlated with coefficient of infection (r= 0.948*), apparent infection rate (r= 0.829*), area under disease progress curve (r= 0988), lesion number (r= 0.967*), lesion area (r= 0.957*) and lesion circumference (r= 0.976*), whereas incubation period (r= -0.858*) was negatively correlated with LBS. The association of coefficient of infection with apparent infection rate (r=0.684*), area under disease progress curve (r=0.936*), lesion number (r=0.959*), leaf area (r=0.961*) and lesion circumference (r=0.960*) was positive and significant, but correlation with incubation period (r= -0.814*) was negative. The correlation coefficients of incubation period with apparent infection rate (r= -0.753*), area under disease progress curve (r= -0.855*), lesion number (r= -0.799*), lesion area (r= -0.813*), and lesion circumference (r= -0.832*) were significant and negative. Significant positive correlation of apparent infection rate with area under disease progress curve (r= 0.824*), lesion number (r= 0.728*), lesion area (r= 0.729*), and lesion circumference (r= 0.761*) was observed. Area under disease progress curve was positively correlated with lesion number (r=0.966*), lesion area (r= 0.941*), and lesion circumference (r= 0.973*). Significant positive correlation of lesion number with lesion area (r= 0.988*), lesion circumference (r= 0.983*) and lesion area with lesion circumference (r= 0.993*) were recorded. Rouman (1992) reported positive correlation of Lesion numbers with leaf blast of rice and the number of lesions in most susceptible cultivars was reported about seven times that in the resistant cultivars.

Conclusion

The results of the present study showed that finger millet cultivars had a diversity of resistance against leaf blast. Two finger millet genotypes namely PR 10-30 and VL 368 were shown resistance against leaf blast. Seven cultivars namely VR 988, VL 352, VL 348, TNAU 1214, GPU 45, VL 369 and KOPN 942 were moderately resistant, whereas 3 cultivars namely PPR 2773, KRI 007-01, VR 708 were susceptible. Two cultivars namely TNAU 1226 and REC 69 were found highly susceptible to leaf blast under artificial inoculations. Lower estimates of coefficient of infection (CI), apparent infection rate (r), area under disease progress curve (AUDPC), percent necrotic area on leaves, number of spots per leaf (LN), length, width, area (LA) and circumference (LC) of lesions were recorded in resistant to moderately resistant genotypes, whereas higher estimate of incubation period (IP) was recorded in susceptible to highly susceptible genotypes of finger millet against leaf blast. A significant positive correlation was found in leaf blast severity with CI (r=0.948*), r (r=0.829*), AUDPC (r=0.998*), LN (r=0.967*), LA (r=0.957*), LC (r=0.976*) whereas, IP (r=-0.825*) was negatively correlated with blast resistance. Present finding suggest that blast being a polycyclic compound interest disease, components of partial resistance may play a important role in arresting the disease development.

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Table 1. Leaf blast severity and estimates of components for evaluation of slow blasting resistance in 14 genotypes of finger millet

S. No.	Cultivars	Leaf blast		Reaction	Coefficient of infection (CI)	Incubation period (hrs)
		Grade	Severity (%)			
1.	PR 10-30	2.0	4.9 (12.78)	R	0.49	96.2
2.	VL 368	2.0	4.7 (15.53)	R	0.47	96.8
3.	TNAU 1226	5.0	51.0 (45.57)	HS	51.00	55.6
4.	VR 988	3.0	21.7 (27.76)	MR	5.43	80.0
5.	VL 352	3.0	23.2 (28.79)	MR	5.80	92.8
6.	VL 348	3.0	14.4 (22.30)	MR	3.60	73.2
7.	PPR 2773	4.0	48.9 (44.36)	S	36.68	61.4
8.	TNAU 1214	3.0	21.7 (27.76)	MR	5.43	76.8
9.	GPU 45	3.0	22.1 (28.03)	MR	5.53	77.2
10.	KRI 007-01	4.0	50.0 (45.00)	S	37.50	52.3
11.	VL 369	3.0	19.8 (26.41)	MR	4.95	72.6
12.	KOPN 942	3.0	23.3 (8.85)	MR	5.83	70.2
13.	VR 708	4.0	26.3 (30.84)	S	19.73	59.9
14.	REC 69	5.0	55.0 (47.87)	HS	55.0	55.0
	GM	3.3	27.65 (30.63)		16.96	72.86
	LSD (5%)	-	1.67		1.77	3.09

*Figures in parentheses are arc sin transformed values
R = resistant MR = Moderately resistant S = Susceptible HS = Highly susceptible

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Table 2. Periodic disease development in slow blasting resistance genotypes of finger millet against leaf blast

S. No.	Genotypes	Necrotic leaf area (%)*				No. of spots/leaf**			
		45 DAS	51 DAS	57 DAS	64 DAS	45 DAS	51 DAS	57 DAS	64 DAS
1	PR 10-30	3.9 (11.44)	4.2 (11.82)	4.8 (12.60)	4.9 (12.31)	0.8 (0.90)	0.9 (0.97)	1.9 (1.40)	2.7 (1.63)
2	VL 368	3.2 (10.34)	3.4 (10.57)	3.9 (11.34)	4.7 (12.53)	1.3 (1.15)	1.5 (1.21)	2.6 (1.60)	3.0 (1.74)
3	TNAU 1226	14.3 (22.21)	23.1 (28.73)	43.3 (41.17)	51.0 (45.57)	3.9 (1.97)	5.4 (2.31)	8.5 (2.92)	10.8 (3.29)
4	VR 988	7.2 (15.60)	11.3 (19.67)	20.0 (26.55)	21.7 (27.82)	1.5 (1.91)	2.2 (1.46)	3.1 (1.75)	3.4 (1.83)
5	VL 352	6.7 (14.96)	9.2 (14.96)	21.7 (27.76)	23.2 (28.80)	2.1 (1.44)	2.6 (1.62)	3.5 (1.86)	4.5 (2.11)
6	VL 348	7.6 (15.97)	10.3 (18.62)	15.0 (22.74)	14.4 (23.32)	1.7 (1.29)	2.5 (1.55)	3.6 (1.90)	3.8 (1.94)
7	PPR 2773	15.5 (23.12)	23.9 (29.24)	43.3 (41.15)	48.9 (44.36)	3.9 (1.97)	5.5 (2.35)	8.8 (2.95)	11.4 (3.37)
8	TNAU 1214	7.9 (16.32)	12.4 (20.61)	20.0 (26.52)	21.7 (27.73)	1.7 (1.30)	2.8 (1.66)	3.8 (1.96)	4.5 (2.11)
9	GPU 45	6.4 (14.70)	12.6 (20.75)	21.7 (27.72)	22.1 (27.36)	1.6 (1.27)	2.2 (1.50)	3.8 (1.95)	4.3 (2.07)
10	KRI 007-01	16.0 (23.59)	25.2 (10.15)	40.0 (39.24)	50.0 (45.00)	4.0 (2.00)	4.8 (2.24)	8.6 (2.93)	11.4 (3.39)
11	VL 369	8.0 (16.40)	13.9 (21.86)	18.0 (25.11)	19.8 (26.41)	1.5 (1.20)	2.7 (1.62)	4.1 (2.00)	4.7 (2.17)
12	KOPN 942	8.7 (17.11)	11.8 (19.98)	21.7 (27.76)	23.3 (28.85)	1.8 (1.33)	2.7 (1.61)	3.8 (1.94)	4.8 (2.18)
13	VR 708	7.3 (15.70)	12.8 (20.92)	20.0 (26.54)	26.3 (30.81)	1.7 (1.30)	2.2 (1.48)	3.2 (1.79)	4.5 (2.11)
14	REC 69	17.5 (24.70)	27.2 (31.46)	43.3 (41.16)	55.0 (47.88)	4.9 (2.21)	7.7 (2.77)	9.9 (3.15)	12.6 (3.55)
	GM	9.3 (17.30)	14.4 (21.3)	25.0 (28.4)	24.6 (30.5)	2.31 (1.47)	3.26 (1.74)	4.8 (2.15)	6.2 (2.4)
	LSD (5%)	1.17	1.17	1.86	1.78	0.19	0.19	0.25	0.19

* ARC sin transformation data **Square root transformation data

Table 3. Apparent infection rate (r) per/unit/day and computed values for area under disease progress curve (AUDPC) in 14 genotypes of finger millet against leaf blast at various stages of growth

S. No.	Genotypes	Infection rate (r)*				AUDPC*
		45-51 DAS	51-57 DAS	57-64 DAS	Average	
1	PR 10-30	0.012	0.012	0.014	0.013	78.6
2	VL 368	0.010	0.023	0.032	0.022	67.5
3	TNAU 1226	0.098	0.145	0.063	0.102	581.7
4	VR 988	0.083	0.119	0.010	0.071	278.1
5	VL 352	0.057	0.173	0.009	0.080	278.1
6	VL 348	0.056	0.057	0.006	0.040	211.2
7	PPR 2773	0.090	0.145	0.041	0.092	593.4
8	TNAU 1214	0.083	0.100	0.010	0.064	286.8
9	GPU 45	0.124	0.102	0.010	0.079	287.7
10	KRI 007-01	0.095	0.125	0.056	0.092	598.2
11	VL 369	0.103	0.036	0.035	0.058	267.0
12	KOPN 942	0.057	0.110	0.027	0.065	260.4
13	VR 708	0.104	0.082	0.066	0.084	294.0
14	REC 69	0.094	0.123	0.074	0.097	644.1
	Average	0.076	0.097	0.032	0.069	337.6

*Average of three replications DAS = days after sowing

Table 4. Lesion size and lesion circumference in 14 finger millet genotypes infected with *Pyricularia grisea* causing leaf blast

S. No.	Genotypes	Lesion size			Lesion circumference (mm)
		Length (mm)	Width (mm)	Area (mm^2)	
1	PR 10-30	5.33	1.67	6.63	10.97
2	VL 368	4.87	1.53	5.57	10.06
3	TNAU1226	13.10	3.53	34.57	26.13
4	VR 988	7.77	1.13	6.40	13.50
5	VL 352	7.47	1.80	10.07	14.57
6	VL 348	7.30	1.90	10.37	14.43
7	PPR 2773	13.90	3.43	35.43	27.23
8	TNAU 1214	8.10	2.00	12.07	15.87
9	GPU 45	7.23	1.77	9.37	14.17
10	KRI 007-01	14.90	3.47	38.37	28.87
11	VL 369	6.333	1.80	8.53	12.77
12	KOPN 942	6.77	2.33	11.77	14.30
13	VR 708	8.73	2.50	16.20	17.67
14	REC 69	16.30	3.67	44.43	31.33
	GM	9.15	2.32	17.84	17.99
	LSD (5%)	0.89	0.66	5.10	1.82

Table 5. Correlation coefficients (r) among components of partial resistance in finger millet against leaf blast

Variables	LBS	CI	IP	r	AUDPC	LN	LA	LC
LBS	1.000	0.948*	-0.858*	0.829*	0.998*	0.967*	0.957*	0.976*
CI		1.000	-0.814*	0.684*	0.936*	0.959*	0.961*	0.960*
IP			1.000	-0.753*	-0.855*	-0.799*	-0.813*	-0.832*
r				1.000	0.824*	0.728*	0.729*	0.761*
AUDPC					1.000	0.966*	0.941*	0.973*
LN						1.000	0.988*	0.983*
LA							1.000	0.993*
LC								1.000

*Significant at 5%

Leaf blast severity (LBS), Coefficient of infection (CI), Incubation period (IP), Apparent infection rate (r), Area under disease progress curve (AUDPC), Lesion number (LN), Lesion area (LA), Lesion circumference (LC)