Resistance in Rice Breeding Lines to the Blast Fungus in Nepal[1]

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ABSTRACT

A total of 36 rice breeding lines including checks were evaluated for resistance to blast at Rampur during 2000-2001. The experiments were conducted under both field condition and greenhouse inoculated condition. Qualitative resistance in rice to blast was assessed based on lesion type, whereas quantitative resistance was assessed based on area under disease progress curve (AUDPC) in the upland field condition. The number of sporulating lesions and the number of leaves with at least one sporulating lesion per plant were considered as measures for evaluation of quantitative resistance in the greenhouse assay. The lesion type, neck blast percentage and AUDPC data suggest that most of the rice lines possess higher level of resistance to leaf and neck blast. The rice lines varied for the number of sporulating lesions and the number of leaves with sporulating lesion per plant. Some lines were incompatible to virulent blast isolates, showing major resistance genes. NR 1558, NR 601-1-1-9, BW306-2 and CN 836-3-10 were promising lines for quantitative resistance to both leaf and neck blast. Radha 12, Sabitri, Janaki possess higher level of quantitative resistance to blast, hence these could be promoted for cultivation in blast-prone environments. These genotypes could also be utilized as donor parents for breeding durable blast resistant varieties. The most virulent blast isolate could be used for evaluation of both qualitative and quantitative resistance to blast in early generation in the greenhouse so that workload could be cut down in future works.

Key words: Blast resistance, field condition, greenhouse assay, *Pyricularia grisea,* rice lines

INTRODUCTION

Blast, caused by *Pyricularia grisea* Sacc., has been a continuous threat to rice production in Nepal (Manandhar 1987, Manandhar et al 1992, Chaudhary 1999). Blast epidemics result in a complete loss of seedlings in the seedbed (Manandhar 1984, Thapa and Manandhar 1985, Adhikari and Shrestha 1986, Pradhanang 1988, Sah 1989, Chaudhary et al 1994, Chaudhary and Sah 1997, Chaudhary and Sah 1998). The farmers often transplant blast infected seedlings that might serve as sources of inoculum for further out-breaks of leaf and neck blast disease in the field (Teng et al 1991). Panicles infected near the base (neck) may break and cause complete yield loss (Ou 1985).

In general, the disease causes 10-20% yield reduction in susceptible varieties, but in severe cases the loss may go up to 80% (Manandhar et al 1992). For 1% increase in the neck blast, a reduction in grain yield had been estimated between 21 to 51 kg ha^{-1} in rice cultivar 'Sankharika' (Manandhar et al 1985). More recently, a grain yield loss of 38.5 and 76.0 kg ha^{-1} was reported in the rice cultivars: 'Masuli' and 'Radha-17', respectively, due to one percent increase in neck blast (Chaudhary 1999).

Seed treatments with systemic fungicides and fungicidal foliar sprays had been demonstrated to be effective in minimizing blast disease (Manandhar 1984, Manandhar et al 1985, Sah and Karki 1988,

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Chaudhary and Sah 1998, Chaudhary 1999). However, the resource-poor farmers are reluctant to use the chemicals prior to occurrence of the disease. The use of chemical is also neither practical nor environment-friendly. Utilization of host resistance has been the best way to manage the disease (Ou 1985, Bonman 1992, Bonman et al 1992). However, blast resistance, especially governed by major genes, is often broken down under field conditions (Kiyosawa 1982, Bonman and Mackill 1988). Therefore, identification of new sources of resistance especially partial resistance and their deployment are necessary for blast management. In this study, 36 advanced rice breeding lines including checks (standard, resistant and susceptible) were evaluated for qualitative and quantitative resistance to blast at Rampur under both field condition and greenhouse inoculated condition during 2000-2001.

MATERIALS AND METHODS

Experiment 1

A total of 35 advanced rice breeding lines promoted for farmer's field trials including resistant and susceptible checks (Table 1) were planted in the upland field conditions. The trial was laid down in a randomized complete block design with three replications. Each genotype was planted in five rows of 0.5 m long as an experimental unit to evaluate for qualitative resistance to blast.

Table 1. Lesion type and percent infection by neck blast in rice genotypes evaluated in the field trials at Rampur, Nepal during the wet season of 2000

SN	Genotype	Lesion type†	Neck blast, %‡	SN	Genotype	Lesion type†	Neck blast, %‡
1	BG 1165-2	0.0	0.08e	19	MLT 119	0.0	0.18e
2	BG 1442	0.1	0.25e	20	NR 1249	0.2	0.40e
3	Bindeshwari	0.7	0.59de	21	NR 1487	0.0	0.53de
4	BR 4684	0.0	0.10e	22	NR 1488	0.1	0.26e
5	BW 306-2	0.0	0.38e	23	NR 1558	2.4	3.74c
6	Chaite 2	0.8	0.66cde	24	NR 1736-4-6	0.0	1.72cde
7	Chaite 4	0.0	0.25e	25	NR 601-1-1-5	0.1	2.02cde
8	Chaite 6	1.4	0.53de	26	NR 601-1-1-9	0.0	0.37e
9	CN 836-3-10	1.5	0.00	27	Radha 11	4.4	15.63b
10	Ghaiya 2	1.0	0.86cde	28	Radha 12	2.5	3.13cd
11	IR 51672	0.0	0.00	29	Radha 32	0.1	0.19e
12	IR 56382	0.0	0.10e	30	Radha 4	0.0	0.29e
13	IR 58115	0.0	0.37e	31	Radha 7	3.6	66.45a
14	IR 59624	0.0	0.13e	32	Radha 9	2.9	11.42b
15	Janaki	0.1	0.12e	33	Rampur Masuli	0.1	0.12e
16	Kalinga 3	1.2	1.29cde	34	Sabitri	1.6	0.00
17	Makwanpur-1	0.1	0.98cde	35	TOX 4004	0.0	0.00
18	Masuli	4.8	20.73b				

† Lesion type was measured on a 0-5 scale; 0-2 = R, 2.1-3 =MR and 3.1-5 = S.
‡ Values followed by the same letter within the column are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

To create blast congenial environment, windbreaks around the experiment and inoculum plots inside the windbreak were managed as per international specifications (Jennings et al 1979). The seedbeds were raised up to 15 cm high above the ground to avoid flooding. The fertilizers were applied at the rate of 150 and 50 kg ha^{-1} of N and P_2O_5, respectively, at the time of planting. Five-gram seed of each line was seeded in a row of 0.5 m long. Weed management was done as needed. Disease evaluation was started 28 days after seeding and continued for three observations at 3-day interval. Six randomly selected seedlings from each plot were rated using a 0-5 scale (Mackill and Bonman 1992). The final data was used to classify the genotypes as resistant (R), moderately resistant (MR) and susceptible (S) types.

The same genotypes were evaluated for resistance to neck blast under transplanted field conditions. The trial was laid down in a randomized complete block design with three replications. The plot size consisted of 10 rows of 1 m length. Single seedling per hill was planted at a spacing of 20- × 15-cm. The fertilizers were applied at the rate of 150 and 50 kg ha^{-1} of N and P_2O_5, respectively. Half N and all P_2O_5 were used as basal at the time of transplanting. The half of the rest nitrogen was uniformly broadcasted at 25 days after transplanting (DAT) and the rest on 40 DAT. Neck blast observation was done 7-10 days before harvesting. Individual panicles were rated as percentage of panicle infected in the neck. Analysis of variance was performed after logarithmic transformation to compare the genotypes for percent neck damage.

Experiment 2

Since the genotypes with 3 or 4 lesion types may have implications on partial resistance (Villareal et al 1980), the genotypes with MR and S lines of experiment 1, along with CO39 as international susceptible check, were re-evaluated for their relative partial resistance under the upland field conditions. Genotypes Chaite 6, Chaite 2, CN 836-3-10 and Kalinga 3, on an average with resistant reaction, also received 3 rating in a few plants in the experiment 1, therefore they were also included in experiment 2.

Five-gram seed of each genotype was planted in 0.5 m long row and each genotype was replicated thrice in randomized complete block design. The planting of spreader rows and fertilizer management was similar to the other upland experiments except windbreak and inoculum rows. Pieces of freshly blast infected leaves collected from the nearby rice fields were spread over the bed uniformly at 20 day after seeding in the evening. The trial bed was routinely sprinkled with water in between 0900 to 1000 h and 1700 to1800 h if it did not rain. After inoculation with freshly infected leaves, the bed was kept covered with polyethylene sheet from 1800 to 0900 h daily until the final observation.

Disease scoring was started from 28 day after seeding. Percentage of diseased leaf area was recorded as the procedure described by Kim et al (1988) and continued for five observations at the 3-day interval. The area under disease progress curve (AUDPC) was calculated using the formula outlined by Shaner and Finney (1977) and analyzed after logarithmic transformation and compared for levels of partial resistance among the genotypes.

Greenhouse Assays

The same 35 advanced rice lines used in experiment 1 (Table 1) along with CO39 as international susceptible check were seeded in the aluminium tray as described by Chaudhary (2001). The experiment was laid out in a randomized complete block design with two replications. The seedlings were inoculated at 21 day after seeding (3-4 leaf stage) with three representative virulent isolates. Inoculum preparation and inoculation were done as described by Chaudhary (2001). Spore suspension of 150 ml for 4 trays was used for inoculation. Disease scoring was done on the seventh day of inoculation on a 0-5 scale as outlined by Mackill and Bonman (1992). The sporulating lesions were counted in each leaf of individual seedlings. The number of sporulating lesions per seedling and the number of leaves at least with one sporulating lesion were calculated.

The rice genotypes were grouped into three categories; R, MR and S based on lesion types, as mentioned in experiment 1. The number of sporulating lesions and the number of leaves at least with one sporulating lesion are the measures for partial resistance to blast (Villareal et al 1981, Yeh and Bonman 1986, Bonman and Mackill 1988, Roumen 1992a, 1992b). These components were analyzed after logarithmic transformation to compare the genotypes for relative partial resistance to blast.

RESULTS AND DISCUSSION

Experiment 1

The rice genotypes varied for qualitative resistance to blast, as measured by lesion type (Table 1). The mean lesion type ranged from 0.0 to 4.8, with Masuli having the highest rating. Twenty-nine of the 35 genotypes showed R to blast. Three genotypes were MR and the rest were susceptible to blast under the field conditions.

The 35 genotypes also differed for neck blast resistance, as measured by percentage of neck infected (Table 1). Neck blast infection varied from 0.0 to 66.45 percent. Radha 7 showed the highest neck blast, whereas Masuli, Radha 11 and Radha 9 had higher percentage of neck blast. Sabitri, TOX 4004 and CN 836-3-10 were completely free from neck blast. Radha 12 had 7-folds less neck blast than that of Masuli. Similarly, NR 1558 and NR 601-1-1-5, the two promising rice lines had, respectively, 6 and 10 times less neck blast than that of Masuli. Other genotypes had lower neck damage due to blast (about > 20 times less) as compared to that of Masuli.

Experiment 2

The AUDPC values ranged from 1.6 to 410 and differed significantly among the 11 genotypes (Table 2). Masuli, CO39 and Radha 11 had higher AUDPC, indicating the higher level of susceptibility to leaf blast. Radha 7 and NR 1558 showed one-third and one-sixth of AUDPC, respectively, in comparison to CO39. The rest genotypes exhibited the AUDPC even significantly lower than NR 1558 suggesting that they have higher level of partial resistance to leaf blast.

Table 2. Area under leaf blast disease progress curve of the rice genotypes tested in upland field at Rampur, Nepal during the wet season of 2000

SN	Genotype	AUDPC[†]
1	BG 1165-2	17.2de
2	BG 1442	79.0bc
3	BW 306-2	5.0ef
4	Chaite 2	43.4cd
5	Chaite 6	1.6f
6	CN 836-3-10	16.4de
7	CO39	288.7a
8	Masuli	410.2a
9	Radha 11	12.0e
10	Radha 7	13.1e
11	Radha 9	153.9ab

[†] AUDPC, Area under disease progress curve. Values followed by the same letters within the column are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

The rice genotypes differed significantly for leaf blast disease severity for all dates (Figure 1). Initially, the differences in blast severity among the rice genotypes were not so pronounced, but over time, it progressed faster in Masuli and CO39 compared to other genotypes (Figure 1). The blast progress in Radha 11 was slower than Masuli and CO39, but faster in comparison to other genotypes, which was reflected by its lower AUDPC than Masuli and CO39 but higher than other genotypes (Table 2). Radha 7 and NR 1558 exhibited intermediate disease progress over time. The rest of the genotypes had 5.0% terminal disease severity values, indicating their higher level of partial resistance.

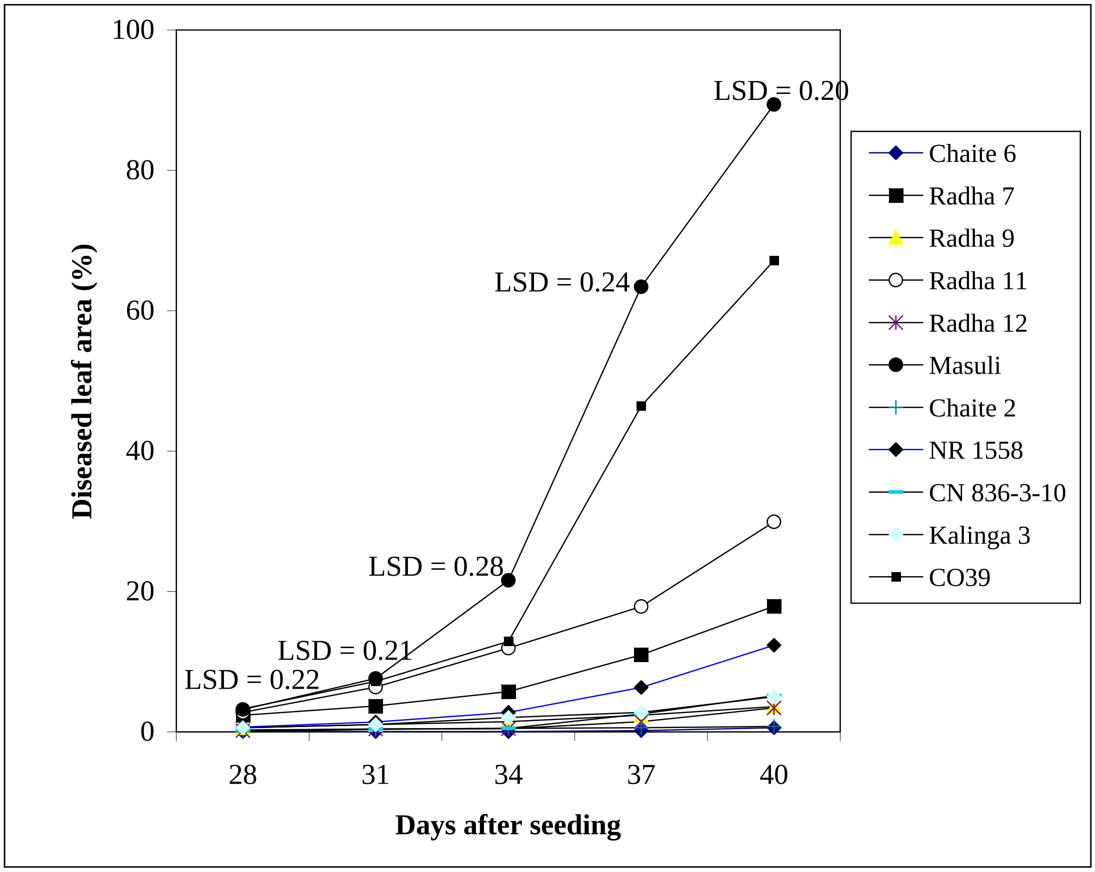

Figure 1. Leaf blast progress curves on rice genotypes evaluated under the upland seedbed conditions at Rampur, Nepal during September to October 2000.

The lesion type, neck blast percentage and AUDPC data suggest that Radha 7, Radha 9, Radha 11 and Masuli are susceptible genotypes. Under field conditions, all the advanced breeding lines possess higher level of resistance to leaf and neck blast. The genotypes having higher rating of leaf blast scored higher percentage of neck blast too; suggesting that compatible inoculum from leaf blast could serve for neck blast infection. A similar finding was reported by Hwang et al (1987). However, there was an exception that statistically, Radha 7 had the highest neck infection, although it had significantly less leaf blast than that of Masuli. This indicates that resistance to neck blast may be expressed in some genotypes of rice independently of that to leaf blast. Gangopadhyay and Padmanabhan (1987) and Chaudhary (1995) reported the similar results. Hence, evaluation of genotypes for both leaf and neck blast is required in field condition before recommendation for release.

Greenhouse assays

The rice genotypes differed for lesion type within and between isolates (Table 3). The lesion type varied from 0.0 to 5.0 in rice seedlings inoculated with different isolates. Isolate K59-1L produced sporulating lesions on 18 rice genotypes, N 22-1L on 13 and Kanto 51-11R on 11.

Table 3. Assessment of blast resistance in rice genotypes as measured by lesion type, the number of leaves at least with one sporulating lesion and the number of lesions per plant under inoculation with three isolates of *Pyricularia grisea* in the greenhouse at Rampur, Nepal during the dry season of 2001

SN	Genotype	K59-1L			N22-1L			Kanto51-11R		
		Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§	Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§	Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§
1	BG 1165-2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	BG 1442	2.0	0.0	0.0	2.0	0.0	0.0	0.5	0.0	0.0
3	Bindeshwari	5.0	1.8ab	14.4abcd	3.5	1.0bcd	3.5def	1.5	0.0	0.0
4	BR 4684	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	BW 306-2	4.0	0.5c	1.5e	0.0	0.0	0.0	1.0	0.0	0.0
6	Chaite 2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	Chaite 4	1.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
8	Chaite 6	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	CN 836-3-10	4.5	1.5ab	10.5cd	4.0	0.9cde	2.4f	3.0	0.9c	1.7cd
10	CO39	5.0	2.5a	25.7ab	5.0	2.1a	12.1a	4.5	1.9b	17.4 a
11	Ghaiya 2	5.0	1.6ab	7.8d	4.0	1.3bc	4.2cde	3.0	0.5de	0.9de
12	IR 51672	1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
13	IR 56382	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
14	IR 58115	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
15	IR 59624	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
16	Janaki	4.0	0.4cd	0.9ef	0.5	0.0	0.0	0.0	0.0	0.0
17	Kalinga 3	3.0	0.6c	1.1ef	3.0	0.2fg	0.4h	3.0	0.4e	0.5 ef
18	Makwanpur-1	2.0	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0
19	Masuli	5.0	2.5a	27.1a	5.0	2.0a	7.8ab	5.0	2.6a	24.8a
20	MLT 119	3.0	0.3cd	1.0ef	0.0	0.0	0.0	0.5	0.0	0.0
21	NR 1249	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	NR 1487	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
23	NR 1488	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	NR 1558	4	0.5c	1.3e	3.5	1.1bc	2.5ef	3.0	0.8cd	3.6c
25	NR 1736-4-6	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
26	NR 601-1-1-5	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
27	NR 601-1-1-9	3.5	0.6c	1.6e	0.0	0.0	0.0	1.0	0.0	0.0
28	Radha 11	5.0	2.2a	18.7abc	4.0	1.9a	6.6bc	5.0	2.3ab	22.3a
29	Radha 12	4.5	1.3b	9.7cd	5.0	0.7d	4.0def	4.0	1.1c	6.7b
30	Radha 32	2.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
31	Radha 4	3.5	0.7c	2.6e	3.5	0.5ef	1.1g	0.0	0.0	0.0
32	Radha 7	5.0	1.9ab	13.9bcd	4.5	1.3b	7.5ab	4.5	1.7b	19.8a
33	Radha 9	5.0	2.4a	15.4abcd	4.0	1.3b	5.4bcd	4.5	2.0ab	27.0a
34	Rampur Masuli	3.0	0.6c	0.9ef	3.0	0.3f	0.3h	3.0	0.5e	0.9de
35	Sabitri	3.0	0.5c	1.4e	1.5	0.0	0.0	0.0	0.0	0.0
36	TOX 4004	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

† Lesion type measured on a 0-5 scale; 0-2 = R, 3 = MR and 3.5-5 = S.

‡ The average number of leaves per plant at least with one sporulating lesion; values followed by the same letters are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

§ The number of sporulating lesions per plant; values followed by the same letters are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

The three isolates produced sporulating lesions in Ghaiya 2, Radha 7, Radha 9, Radha 11, Radha 12, Masuli, Rampur Masuli, NR 1558, CN 836-3-10, Kalinga 3 and CO 39. Isolate N22-1L produced sporulating lesion in Bindeswari and Radha 4 in addition to that of 11 genotypes. Isolate K59-1L produced sporulating lesions in Janaki, Sabitri, NR 601-1-1-9, BW 306-2 and MLT 119 in addition to the genotypes showing the sporulating lesions when inoculated with N22-1L.

The rice lines varied for the number of sporulating lesions per plant and the number of leaves with sporulating lesion per plant for an isolate (Table 3). Masuli and CO39 had always the highest number of lesions and leaves with at least one sporulating lesion.

Comparable to Masuli and CO39, Radha 7, Radha 9 and Radha 11 consistently exhibited lower number of sporulating lesions per plant and leaves with such lesions per plant inoculated with each of the isolates. Under field conditions, Radha 7 and Radha 9 showed lower leaf blast but similar or higher neck blast compared to Masuli. This indicated that greenhouse inoculation assays could precisely identify or assess level of blast resistance in the genotypes; hence, greenhouse inoculation assays should be adopted for such works.

Ghaiya 2, Radha 12 and Rampur Masuli had significantly less number of lesions and fewer leaves with lesions compared to Masuli, indicating that they have a good level of partial resistance. Radha 12 had also significantly less percentage of neck blast and the slower disease development in the field conditions (Table 1 and 2).

Janaki and Sabitri had the lowest leaves with sporulating lesions. They also produced the least number of lesions per plant among the genotypes. This explains why these varieties have been observed consistent in the farmer's field. NR 601-1-1-9 and BW 306-2 also had significantly lower number of leaves having less number of lesions per plant compared to Masuli (Table 3). In most cases, the genotypes having higher number of sporulating lesions had the higher number of leaves with lesion, indicating positive association between them similar to that of earlier report (Roumen 1992a, Roumen 1996). This suggests that the number of leaves with sporulating lesions could be used as the easier and faster criterion for selection and improvement of partial resistance in rice to blast.

Majority of the rice lines possess major blast resistance genes. Among the recommended genotypes Chaite 2, Chaite 4, Chaite 6 and Makwanpur 1 showed hypersensitive reaction to all the three isolates, indicating that they have major genes for resistance to the blast pathogen.

All isolates produced sporulating lesions on seedlings of NR 1558, CN 836-3-10 and Kalinga 3. However, these lines had significantly fewer leaves with lower number of sporulating lesions as compared to Masuli. This indicates that these lines possess quantitative resistance according to report of Van der Plank (1968) that varieties with quantitative resistance are equally effective against all isolates.

The results suggest that evaluation for partial resistance in rice to blast could be done by the inoculation with a single virulent isolate. The similar recommendation was proposed by Imbe et al (2000). Due to high association between partial resistance and durable resistance to blast (Bonman and Mackill 1988), selection for partial resistance might help extend longevity of resistance in rice genotypes to blast. Also, the number of leaves with sporulating lesions could be used as a component of partial resistance to blast.

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