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Research article-Development of hybrids resistant to cold and leaf blast in rice (*Oryza sativa.* L)

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ABSTRACT

The experiment was conducted using 24 parental lines, which included four female lines crossed with twenty elite, diverse, and proven restorer lines to develop 80 experimental hybrids during the kharif season of 2019. The objective was to screen for cold and blast resistance during the rabi season of 2019-20, along with susceptible and resistant checks. Pooled data from cold screening showed that, out of 104 lines, 20 lines exhibited strong tolerance (ST), 76 lines showed tolerance (T), and 8 lines displayed moderate tolerance. None of the lines, except the susceptible checks, recorded sensitive or highly sensitive reactions. Out of 104 entries screened for blast, 73 entries were identified as resistant (R), 21 lines as moderately resistant (MR), and 10 lines as susceptible. The checks TN1 was found to be highly susceptible, while US 314 was resistant (IRRI-SES, 2013). Based on cold and blast scoring data, among the 20 restorer lines, 10 lines showed tolerance to cold and resistance to leaf blast. Ten restorer lines, namely RNR 26085, ZGY 1, RNR 2354, RNR 28359, RNR 28411, RNR 21571, IR 72, JGL 35126, JGL 35047, and JGL 34551, were selected and further utilized for combining ability, heterosis, and stability studies.

Keywords: *Rice, Hybrids, Cold screening and Blast screening*

INTRODUCTION

Rice is a staple food crop of India and occupiesapivotal place in Indian agriculture. It is the staple food for two-thirds of the world`s population, providing 43 percent of calorie requirement and 20-25% of agricultural income. Rice occupies more than 23% of gross cropped area in India (about 43.8 million ha.) which is the largest in the world among all the rice growing countries. Annual production of rice in the country is around 1378.25LMT with an average productivity of 4300 kg per hectare (Department of Agricultural Co-operation &Farmers Welfare, 2023-24).Rice is most important food crop of Telangana and has cultivated122.45 lakh acres of paddy, resulting in a production of 258 LMTand an average productivity of 5270 kg per ha. (Directorate of Economics and Statistics, Telangana socio economic outlook, 2023-24).

Among the biotic factors diseases are the most important factor resulting in crop losses of $ 5 billion every year (Asghar*et al.*, 2007). Rice blast, which is caused by the fungal pathogen *Magnaportheoryzae,* is one of the most serious diseases of rice, breaks out frequently in paddy field worldwide, and reduces yields of rice by 10–35% annually (Li *et al.* 2019). Rice blast is one of the most destructive and wide spread disease (Jia*et al.*, 2000). Blast was first reported in Asia over three centuries ago and is now present in more than85 countries.

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It is highly adaptable to environmental conditions and can be found in irrigated lowland, rainfed upland, or deep-water rice fields (Rao, 1994).

Symptoms of leaf blast typically consist of elongated diamond-shaped lesions with gray or whitish centers and brown or reddish brown margins followed by stunted growth, a reduced number of bearing panicles and weight of individual grains. Infection of stem nodes results in barren panicles; late neck infection (after grain filling) results in 'broken necks'. Similarly, panicle and neck blast also reduce rice milling yield, bulk density of the grain and increase the number of fissured kernels (Candole*et al.,* 1999). Panicle blast and node blast can stop grain formation and lead to crop failure (Li and Zhang, 2015).

The disease results in yield loss as high as 70-80% (Ou, 1985) when predisposingfactors (high mean temperature values, degree of relative humidity higher than 85-90%, presence of dew, drought stress and excessive nitrogen fertilization) favour epidemic development (Piotti*et al.,* 2005).

Among the abiotic factors cold is an important stress which results in yield losses of the rice crop. The cold tolerance at one developmental stage is therefore not necessarily correlated with the tolerance at other stages (Foolad, 2001). It has been demonstrated that cold tolerance at the vegetative growth stage is independent of that at the reproductive growth stage of rice (Kaw *et al.* 1986). Thus, there is a need to develop methodsfor evaluating cold tolerance for each developmental stage of rice life cycle by carefullyexaminingof morphological changes in each developmental stage under the stress (Foolad 2001).

Cold stress at the seedling stage and high temperatures at flowering stage occur in the subtropical regionswhere rice is cultivated.

In the temperate regions rice growth is constrained by the limited period that favours growth requiring optimum temperature between 25°C to 35°C and temperatures below this range often result in poor seedling vigour (Reyes *et al.,* 2003). Temperatures below 25°C would cause growth abnormalities in temperate and high-elevated tropical rice growing areas (Fujino*et al.,* 2004; Sthapit and Witcombe, 1998).

Certain morpho-physiological traits such as seedling vigour and leaf yellowing have beenidentified as selection criteria for cold tolerance (Mahender*et al.,* 2015). Similarly various endogenous biochemical compounds have been attributed to tolerance against low temperature in rice. Cold-tolerant rice cultivars accumulate high amount of spermine (a natural-polyamine). Non-reducing sugar and phenolcontent were most Efficientbiochemicalmarkers for screening cold tolerant genotypes at seedling stage (Parmanand*et al.,* 2018).Therefore developing rice cultivars with considerable level of cold tolerance is needed.

With this background the present study entitled "Development of hybrids resistant to cold and leaf blast in rice (*Oryza sativa L.*)" was carried out.

MATERIALS AND METHODS

1 Experimental material

The experiment was conducted using 24 parental lines which includes four females crossed with twenty elite diverse proven restorer lines to develop 80 experimental hybrids during *Kharif*2019 to screen for cold and blast resistance during *rabi* 2019-20 along with six checks (3 resistant and 3 susceptible).

2. Experimental sites

The experiment was carried out in following two different experimental locations to screen the hybrids against leaf blast and cold stress.

1. Regional Agricultural Research Station (RARS), Polasa, Jagtial.
2. Rice Research Center ARI, Rajendranagar.

Eighty crosses were obtained involving four CMS lines and twenty elite restorers in a line × tester fashion during *Kharif*-2019 at RARS, Jagtial. Three staggered sowings of the males were undertaken at an interval of 10 days to ensure synchronous flowering to make crosses. Twenty-eight days old seedlings were transplanted at a spacing of 20 cm ×15 cm. A recommended package of practices was followed to raise healthy crop and to produce adequate crossed seed.

During *Rabi* 2019-20, screening of hybrids for leaf blast resistance through Uniform Blast Nursery (UBN) and screening of nurseries for cold stress was carried out along with standard checks.

3. Cold screening

Eighty hybrids along with 24 parents, two susceptible and two resistant checks were sown on 7th December in 10 m × 1 m nursery beds for cold screening during *rabi*2019-20 at RARS, Jagtial and 24th December, at Rice Research Centre, ARI, Rajendranagar under natural field condition. The maximum and minimum temperatures during this period recorded were 17.8 0C and 13.1 0C respectively at RARS, Jagtial. The maximum and minimum temperatures recorded for Rice Research Centre, ARI, Rajendranagar were 16.8 0C and 12.9 0C. Chlorophyll content through SPAD meter was recorded at normal temperature and cold stress conditions for 5 days to assess leaf chlorophyll concentration. Scoring for cold tolerance was done according to the Standard Evaluation System for Rice (IRRI-SES, 2013, 5th edition) at the time of yellowing of leaf was observed in susceptible checks.

3.1 SPAD chlorophyll reading: SPAD chlorophyll readings were recorded on five randomly selected plants for each entry using SPAD meter at normal temperature and cold stress condition during the nursery stage.

3.2 Decrease of SPAD reading (%): The percentage decrease of SPAD reading was calculated by using following formula.

$$\text{Decrease of SPAD reading (\%)} = \frac{\text{SPAD at normal temp.} - \text{SPAD atlow temp.}}{\text{SPAD at normal temperature}}$$

3.3 Yellowing score (0-9 scale) for cold tolerance (IRRI-SES, 2013, 5th edition): Scoring was done by visual observation of each genotype based on IRRI-SES 2013.

4. Blast screening

Eighty hybrids along with 24 parents, susceptible and resistant checks were sown in UBN at RARS, Jagtial and Rice Research Centre, ARI, Rajendranagar under natural field condition.

The inoculum was sprayed at 15-day-old seedlings in the evening till the entire plant surface became wet with spore suspension and left overnight. Water was sprayed three to four times during thetime to maintain high humidity.

4.1. Blast scoring: Scoring was done after 10-15 days of post infection depending on the severity of the infection on each entry and susceptible check using the Standard Evaluation System.Based on leaf blast scores recorded,the genotypes were declared resistant (0- 3), moderately resistant (4- 5) and susceptible (6-9).

4.2. Blast incidence (0-9 scale): Blast score was recorded on five randomly selected leaves for each entry.

As these two traits, *viz.,* cold (Cruz *et al.,* 2006) and blast (Divya*et al.,* 2014) were governed by dominant genes, so the resulted hybrids from these parents would have expected to resistant to blast and tolerant to cold.

Based on cold stress and blast reaction data, hybrids and parents were identified. The selected parents were crossed in L × T fashion for studying combining ability, heterosis and stability.

RESULTS AND DISCUSSIONS

Identification of blast and cold tolerant parental lines and development ofhybrids

Twenty known restorer lines and fourcytoplasmic male sterile lines were selected and developed 80 hybrids during *kharif*2019. These hybrids along with parental lines and suitable checks were evaluated for cold stress and blast incidence at RARS, Jagtial and Rice Research Centre, ARI, Rajendranagar.

Screening for cold tolerance

A Total of 108 genotypes (24 parents, 80 hybrids and four checks) including resistant and susceptible checks were sown at RARS, Jagtial and Rice Research Center, Agriculture Research Institute, Rajendranagar, Hyderabad during *Rabi 2019-20*for cold screening under natural field condition. The maximum and minimum temperatures during the nursery growth were recorded. During the nursery stage the crop was exposed to normal as well as low temperature at both the locations enablingthe recording of SPAD readings during two different time points. At RARS, JGL the average minimum temperature during the previous 5 days of recording SPAD observations was

17.8^{0}C(normal temperature exposed period 23.12.2019 to 27.12.2019) and 13.1^{0}C (low temperature exposed period 28.12.2019 to 01.01.2020).Similarly at RRC, RNR the average minimum temperatures recorded were 16.8^{0}C and 12.9 ^{0}C for normal and low-temperature exposed period respectively.

SPAD chlorophyll meter readings were recorded atnormal temperature and low temperature exposed period (at least 5 days period) to assess leaf chlorophyll concentration.Yellowing score was recorded at low temperature exposed period.

SPAD Readings

At Jagtial location, SPAD readings at normal temperature (17.8°C) ranged from 20.1 to 31.9 with an overall mean of 26.5 (Table 1). Among the lines, it ranged from 24.6 (JMS 13B) to 30.3 (CMS 46B) and in testers it rangedfrom 22.8 (TP 30211) to 28.9 (TP 30022). Hybrids showed a wide range, from 20.1 (CMS 46A × RNR 28361) to 31.9 (CMS 59A × RNR 21571). Among the checks, it ranged from 20.4 (JGL 1798) to 29 (JGL 24423). At low temperature condition (13.1°C), SPAD readings ranged from 15.1 to 27.1 with an overall mean of 21.9. In lines, it ranged from 19.9 (JMS 13A) to 25.1 (CMS 46A) and in testers, it ranged from 15.3 (TP 30211) to 27.1 (TP 30022). Hybrids recorded a range of 15.1 (CMS 23A ×JGL 18047) to 26.4 (JMS 13A ×RNR 28361 & CMS 59A × RNR 21571). In checks, it ranged from 15.7 (JGL 1798) to 26.4 (JGL 24423).

Variation in SPAD readings at normal temperature(16.8°C) in Rajendranagar location was from 20.4 to 31.9 with a mean of 25.4. Lines recorded a range of 23.9 (JMS 13B) to 25.8 (CMS 46B) and testers recorded between 20.8 (TP 30211) to 27.6 (JGL 34551). In hybrids, the range was from 20.4 (CMS 23A × IR 72) to 31.9 (JMS 13A × RNR 28361). At low-temperature condition (12.9°C) in Rajendranagar varied from 15.3 to 26.8 with a mean of 20.9. The lines exhibited a range of 18.9 (JMS 13B) to 20.6 (CMS 23B) and the testers showed a range of 16.3 (MTU 1153) to 23.1 (TP 30022). In hybrids, the range was from 15.3 (CMS 59A × JGL 33508) to 26.8 (CMS 59A × MTU 1153). In checks, it was recorded from 14.9 (JGL 1798) to 23.6 (JGL 24423).

The pooled data over locations showed that a SPAD reading at normal temperature(17.3°C) condition was from 21.2 to 31.3 with an overall mean of 26.0. For lines, it ranged from 24.3 (JMS 13B) to 28.1 (CMS 46B), and for testers the range was between 21.8 (TP 30211) and 27.9 (TP 30022), while in hybrids, the range varied from 21.2 (CMS 46A × RNR 28361) to 31.3 (CMS 13A × RNR 28361). In checks, it was ranged from 22.6 (JGL 1798) to 28.8 (JGL 24423).At cold temperature(13.0°C), it varied from 15.9 to 26.9 with a mean of 21.4, in lines exhibited a range of 19.4 (JMS 13B) to 22.6 (CMS 46B) and for testers showed a range of 15.9 (TP 30211) to 25.1 (TP 30022). Hybrids showed a range of 16.1 (JMS 59A × JGL 33508) to 26.9 (CMS 59A × RNR 28344), while in checks, the range was from 15.3 (JGL 1978) to 25.0 (JGL 24423).

Decrease of SPAD readings (%)

In pooled data, the percentage decrease inSPAD readings ranged from 7.4 to 29.9 with an overall mean of 17.6. In the lines, it ranged from 16.3 (CMS 23B) to 20.0 (JMS 13B) and testers exhibited range of 9.9 (TP 30022) to 27.3 (TP 30211). The Hybrids showed a range of 7.4 (CMS 59A × JGL 35126) to 29.9 (CMS 23A × JGL 18047), while in checks, it ranged from 13.0 (JGL 24423) to 33.0 (JGL 11470).

Among the 80 hybrids and 24 parents evaluated, 19 hybrids recorded less than 10 percent decrease inSPAD readings, indicating astrongly tolerant reaction tolow temperature stress.Additionally55 hybrids recorded percent decrease of SPAD readings between 10-20 with tolerant reaction. However, 6 hybrids were identified as moderately tolerant with a 20-30 percent decrease in SPAD reading. The susceptible reaction was observed only in checks JGL 11470 & JGL 1798.

Yellowing score

At Jagtial location, for yellowing score 27 hybrids recorded 0-1 score with strongly tolerant reaction, 49 hybrids recorded 2-3 score with tolerant reaction and 4 hybrids recorded moderately tolerant reaction with 4-5 score.

Variation in yellowing score at RRC, Rajendranagar revealed that, 32 hybrids recorded 0-1 score with strongly tolerant reaction, 44 hybrids recorded 2-3 score with tolerant reaction and 4 hybrids recorded moderately tolerant reaction with 4-5 score. Susceptible checks (JGL 11470 and JGL 1798) recorded 6-7 score with sensitive reaction and tolerant checks (JGL 24434 &Tellahamsa) recorded 2-3 score.

Pooled data for yellowing score, 19 hybrids recorded 0-1 score with strongly tolerant reaction,55 hybrids recorded 2-3 score with tolerant reaction and 6 hybrids recorded moderately tolerant reaction with 4-5 score.Except two testers, all the parents recorded tolerant reaction.

Table 1 Reaction of parental lines, hybrids and checks evaluated for cold incidence

S. No.		SPAD Readings(RARS, Jagtial)		SPAD Readings (ARI, Rajendranagar)		SPAD Readings Pooled		% decrease of SPAD reading	Yellowing score (RARS), Jagtial	Yellowing score(ARI), Rajendranagar	Yellowing score pooled	Cold Reaction
	Parents/Hybrids	At normal temp.	At low temp.	At normal temp.	At low temp.	At normal temp.	At low temp.					
	Lines											
1	JMS 13B	24.6	19.9	23.9	18.9	24.3	19.4	20.0	3	3	3	T
2	CMS 23B	28.6	24.1	24.8	20.6	26.7	22.4	16.3	3	3	3	T
3	CMS 46B	30.3	25.1	25.8	20.1	28.1	22.6	19.4	1	3	2	T
4	CMS 59B	28.7	22.9	24.8	20.4	26.8	21.7	19.1	1	3	2	T
	Mean	**28.1**	**23.0**	**24.8**	**20.0**	**26.4**	**21.5**	**18.3**	**2**	**3**	**3**	
	Testers											
5	RNR 26085	24.8	19.4	22.6	19.5	23.7	19.5	17.9	3	3	3	T
6	ZGY 1	23.4	18.9	25.2	21.1	24.3	20.0	17.7	3	3	3	T
7	TP 30022	28.9	27.1	26.8	23.1	27.9	25.1	9.9	1	1	1	ST
8	TP 30211	22.8	15.3	20.8	16.4	21.8	15.9	27.3	3	5	4	MT

9	RNR 2354	26.9	22.5	23.7	20.8	25.3	21.7	14.4	3	3	3	T
10	MTU 1153	23.1	19.4	21.0	16.3	22.1	17.9	19.0	3	3	3	T
11	RNR 28359	24.8	19.7	28.6	23.1	26.7	21.4	19.9	3	3	3	T
12	RNR 28411	30.3	25.2	26.9	21.5	28.6	23.4	18.4	1	3	2	T
13	MTU 1260	26.1	22.3	28.4	23.2	27.3	22.8	16.5	3	3	3	T
14	RNR 21571	25.9	20.2	22.1	18.6	24.0	19.4	19.2	3	3	3	T
15	RNR 28361	23.6	20.8	21.9	17.2	22.8	19.0	16.5	3	3	3	T
16	RNR 28344	26.4	22.9	22.3	18.1	24.4	20.5	15.8	3	3	3	T
17	IRTON 270	27.8	23.2	23.7	19.3	25.8	21.3	17.5	3	3	3	T
18	IR 72	25.6	23.1	26.8	20.7	26.2	21.9	16.4	2	2	2	T
19	JGL 35126	23.8	19.6	25.2	20.5	24.5	20.1	18.2	3	3	3	T
20	JGL 18047	29.2	23.9	22.6	17.5	25.9	20.7	20.1	1	3	2	T
21	JGL 35047	26.9	21.7	23.7	19.4	25.3	20.6	18.8	3	3	3	T
22	JGL 34551	20.6	16.4	27.6	22.3	24.1	19.4	19.7	3	3	3	T
23	JGL 33508	25.6	19.3	27.4	19.4	26.5	19.4	27.0	3	5	4	MT
24	JGL 34452	23.6	20.2	21.9	18.4	22.8	19.3	15.2	3	3	3	T
	Mean	**25.5**	**21.1**	**24.5**	**19.8**	**25.0**	**20.4**	**18.3**	**3**	**3**	**3**	
	Parental mean	**26.8**	**22.0**	**24.6**	**19.9**	**25.7**	**21.0**	**18.3**	**2**	**3**	**3**	
	Hybrids											
25	JMS 13A × RNR 26085	24.9	20.8	25.6	19.8	25.3	20.3	19.6	3	1	2	T
26	JMS 13A × ZGY 1	29.8	23.5	29.5	24.7	29.7	24.1	18.7	1	3	2	T
27	JMS 13A × TP 30022	26.4	24.2	25.7	23.8	26.1	24.0	7.9	1	1	1	ST
28	JMS 13A × TP 30211	26.8	19.8	24.9	18.1	25.9	19.0	26.7	5	3	4	MT
29	JMS 13A × RNR 2354	28.2	22.5	29.3	23.6	28.8	23.1	19.8	3	3	3	T
30	JMS 13A × MTU 1153	22.1	18.3	25.6	20.4	23.8	19.4	18.8	3	3	3	T
31	JMS 13A × RNR 28359	27.8	23.5	29.5	22.4	28.7	23.0	19.9	3	1	2	T
32	JMS 13A × RNR 28411	29.2	22.9	30.9	26.3	30.1	24.6	18.1	3	3	3	T
33	JMS 13A × MTU 1260	28.1	23.4	28.7	22.4	28.4	22.9	19.3	1	3	2	T
34	JMS 13A × RNR 21571	25.8	20.8	27.1	22	26.5	21.4	19.2	3	1	2	T
35	JMS 13A × RNR 28361	30.6	26.4	31.9	25.8	31.3	26.1	16.5	3	1	2	T
36	JMS 13A × RNR 28344	22.3	19.2	24.9	21.3	23.6	20.3	14.2	3	3	3	T
37	JMS 13A × IRTON 270	30.1	24.2	29.7	23.6	29.9	23.9	20.1	3	3	3	T
38	JMS 13A × IR 72	31.5	25.4	30.5	24.2	31.0	24.8	20.0	1	3	2	T
39	JMS 13A × JGL 35126	28.3	22.6	26.7	22.3	27.5	22.5	18.4	1	3	2	T
40	JMS 13A × JGL 18047	25.8	23.4	24.3	23	25.1	23.2	7.4	1	1	1	ST
41	JMS 13A × JGL 35047	28.9	24.3	26.9	21.6	27.9	23.0	17.8	3	1	2	T
42	JMS 13A × JGL 34551	27.0	21.3	24.1	22.3	25.6	21.8	14.7	3	3	3	T
43	JMS 13A × JGL 33508	24.4	18.3	23.6	16.2	24.0	17.3	28.1	3	5	4	MT
44	JMS 13A × JGL 34452	24.9	20.1	26.7	22.4	25.8	21.3	17.7	3	3	3	T
45	CMS 23A × RNR 26085	23.9	19.3	25.8	20.7	24.9	20.0	19.5	3	3	3	T
46	CMS 23A × ZGY 1	28.5	22.1	24.8	20.9	26.7	21.5	19.4	2	2	2	T
47	CMS 23A × TP 30022	26.6	23.7	25.0	22.9	25.8	23.3	9.7	1	1	1	ST
48	CMS 23A × TP 30211	29.5	24	26.1	23.2	27.8	23.6	15.2	3	3	3	T
49	CMS 23A × RNR 2354	26.8	23.9	24.6	22.6	25.7	23.3	9.4	1	1	1	ST
50	CMS 23A × MTU 1153	25.6	18.9	23.3	16.4	24.5	17.7	27.8	5	5	5	MT

51	CMS 23A × RNR 28359	25.4	22.6	27.0	25.1	26.2	23.9	9.0	1	1	1	ST
52	CMS 23A × RNR 28411	29.1	23.6	28.6	22.8	28.9	23.2	19.6	2	2	2	T
53	CMS 23A × MTU 1260	25.2	20.1	27.6	23.2	26.4	21.7	18.0	3	3	3	T
54	CMS 23A × RNR 21571	26.7	24.6	25.8	22.8	26.3	23.7	9.7	1	1	1	ST
55	CMS 23A × RNR 28361	24.3	19.1	27.7	22.9	26.0	21.0	19.2	3	3	3	T
56	CMS 23A × RNR 28344	22.7	17.4	25.4	21.3	24.1	19.4	19.5	3	3	3	T
57	CMS 23A × IRTON 270	24.5	19.3	25.7	21.5	25.1	20.4	18.8	3	3	3	T
58	CMS 23A × IR 72	22.4	17.8	20.4	18.3	21.4	18.1	15.6	3	3	3	T
59	CMS 23A × JGL 35126	24.9	19.3	23.6	20.2	24.2	19.8	18.5	3	1	2	T
60	CMS 23A × JGL 18047	24.5	15.1	23.2	18.3	23.8	16.7	29.9	5	3	4	MT
61	CMS 23A × JGL 35047	27.0	25.3	28.2	24.7	27.6	25.0	9.4	1	1	1	ST
62	CMS 23A × JGL 34551	28.5	23.7	28.6	22.1	28.5	22.9	19.7	3	3	3	T
63	CMS 23A × JGL 33508	23.6	19.4	25.1	20.6	24.3	20.0	17.8	3	3	3	T
64	CMS 23A × JGL 34452	26.8	24.6	27.4	24.4	27.1	24.5	9.6	1	1	1	ST
65	CMS 46A × RNR 26085	27.3	24.6	27.9	25.8	27.6	25.2	8.7	1	1	1	ST
66	CMS 46A × ZGY 1	28.1	26.2	28.6	25.4	28.3	25.8	9.0	1	1	1	ST
67	CMS 46A × TP 30022	26.2	22.9	24.2	23.1	25.2	23.0	8.7	1	1	1	ST
68	CMS 46A × TP 30211	23.8	19.4	22.6	18.3	23.2	18.9	18.8	3	3	3	T
69	CMS 46A × RNR 2354	22.6	18.5	24.9	19.5	23.8	19.0	20.0	3	3	3	T
70	CMS 46A × MTU 1153	24.6	22.3	27.4	25.7	26.0	24.0	7.7	1	1	1	ST
71	CMS 46A × RNR 28359	23.9	19.5	25.4	20.3	24.7	19.9	19.3	3	3	3	T
72	CMS 46A × RNR 28411	28.0	25.2	27.6	25.3	27.8	25.3	9.2	1	1	1	ST
73	CMS 46A × MTU 1260	25.3	20.4	24.2	19.6	24.8	20.0	19.2	3	3	3	T
74	CMS 46A × RNR 21571	26.1	21.4	27.6	23.3	26.9	22.4	16.8	3	3	3	T
75	CMS 46A × RNR 28361	20.1	16.8	22.3	17.5	21.2	17.2	19.3	3	3	3	T
76	CMS 46A × RNR 28344	26.2	22.5	24.5	19.1	25.3	20.8	17.9	3	3	3	T
77	CMS 46A × IRTON 270	25.8	23.4	23.2	21.5	24.5	22.5	8.3	1	1	1	ST
78	CMS 46A × IR 72	27.9	23.2	28.1	24.7	28.0	24.0	14.5	3	1	2	T
79	CMS 46A × JGL 35126	27.6	22.1	25.9	21.7	26.8	21.9	18.2	3	3	3	T
80	CMS 46A × JGL 18047	24.6	19.5	26.2	21.9	25.4	20.7	18.5	3	3	3	T
81	CMS 46A × JGL 35047	27.9	23.2	25.6	21.8	26.7	22.5	15.8	1	3	2	T
82	CMS 46A × JGL 34551	29.0	23.6	27.1	22.6	28.0	23.1	17.6	1	3	2	T
83	CMS 46A × JGL 33508	24.4	21.8	25.3	23.6	24.9	22.7	8.7	1	1	1	ST
84	CMS 46A × JGL 34452	26.5	23.7	27.4	24.8	27.0	24.3	10.0	1	1	1	ST
85	CMS 59A × RNR 26085	25.3	21.7	27.2	22.9	26.3	22.3	15.0	3	1	2	T
86	CMS 59A × ZGY 1	24.3	19.3	22.8	18.4	23.6	18.9	20.0	3	1	2	T

87	CMS 59A × TP 30022	25.2	18.7	23.0	20.1	24.1	19.4	19.5	1	3	2	T
88	CMS 59A × TP 30211	30.3	24.8	29.9	23.8	30.1	24.3	19.3	3	1	2	T
89	CMS 59A × RNR 2354	26.3	22.5	24.6	20.3	25.5	21.4	15.9	3	3	3	T
90	CMS 59A × MTU 1153	28.2	25.6	29.5	26.8	28.9	26.2	9.2	1	1	1	ST
91	CMS 59A × RNR 28359	24.9	20.3	26.4	21.5	25.7	20.9	18.5	3	3	3	T
92	CMS 59A × RNR 28411	30.0	23.7	30.8	26.8	30.4	25.3	17.0	3	1	2	T
93	CMS 59A × MTU 1260	24.5	20.4	26.2	22.1	25.4	21.3	16.2	1	3	2	T
94	CMS 59A × RNR 21571	31.9	26.4	28.4	22.6	30.2	24.5	18.8	3	3	3	T
95	CMS 59A × RNR 28361	27.9	22.6	25.8	20.4	26.9	21.5	19.9	3	3	3	T
96	CMS 59A × RNR 28344	29.6	27.1	30.1	26.7	29.9	26.9	9.9	1	1	1	ST
97	CMS 59A × IRTON 270	23.3	19.6	24.8	19	24.1	19.3	19.8	3	3	3	T
98	CMS 59A × IR 72	20.3	15.4	22.0	18.8	21.2	17.1	19.1	3	3	3	T
99	CMS 59A × JGL 35126	27.6	25.8	25.3	23.2	26.5	24.5	7.4	1	1	1	ST
100	CMS 59A × JGL 18047	25.7	22.6	27.4	23.5	26.6	23.1	13.2	3	3	3	T
101	CMS 59A × JGL 35047	23.1	20.1	24.7	19.9	23.9	20.0	16.3	3	1	2	T
102	CMS 59A × JGL 34551	23.9	20.3	25.3	19.7	24.6	20.0	18.7	3	1	2	T
103	CMS 59A × JGL 33508	23.6	16.9	22.3	15.3	23.0	16.1	29.8	3	5	4	MT
104	CMS 59A × JGL 34452	25.7	18.6	23.5	16.8	24.6	17.7	28.0	5	5	5	MT
	Mean of crosses	**26.2**	**21.8**	**26.2**	**21.9**	**26.2**	**21.9**	**16.7**	**2**	**2**	**2**	
	Grand mean	**26.5**	**21.9**	**25.4**	**20.9**	**26.0**	**21.4**	**17.5**	**2**	**3**	**3**	
	Checks											
	JGL 24423	29	26.4	28.5	23.6	28.8	25.0	13.0	2	2	2	T
	Tellahamsa	24.6	21.4	26.8	22.3	25.7	21.9	15.0	3	3	3	T
	JGL 11470	22.7	16.3	24.9	15.6	23.8	16.0	33.0	5	7	6	S
	JGL 1798	20.4	15.7	24.7	14.9	22.6	15.3	32.2	7	7	7	S
	Checks Mean	**24.2**	**20.0**	**26.2**	**19.1**	**25.2**	**19.5**	**23.3**	**4**	**5**	**5**	
	Avg.Min.Temp.	17.8	13.1	16.8	12.9	17.3	13.0					
	Temp.Range during five days	30.0-15.5	28.0-11.5	30.0-18.5	30.5-11							

During previous five days at Jagtial from 23.12.2019 to 27.12.2019 (Normal temperature exposed period) and 28.12.2019 to 01.01.2020 (Low temperature exposed period)

During previous five days at R'nagar from 17.01.2020 to 21.01.2020 (Normal temperature exposed period) and 11.01.2020 to 15.01.2020(Low temperature exposed period) Based on the percentage decrease in SPAD chlorophyll meter reading and yellowing scores, out of 104 lines, 20 lines have shown a strongly tolerant (ST) reaction, 76 lines have shown a tolerant (T) reaction, and 8 lines have shown a moderately tolerant reaction. None of the lines, except the susceptible checks, recorded sensitive or highly sensitive reactions.

Plate 1: Cold telerant and suceptible checks along with cold tolerant hybrids

Plate 2 Recording of SPAD readings

a. Recording of SPAD reading at low temperature condition

b. Recording of SPAD reading at normal temperature condition

Screening for blast resistance

Total one hundred and sixgenotypes (24 parents, 80 hybrids and 2 checks) includingresistant (US 314) and susceptible (TN 1) checkswere sown in UBN atRARS, Jagtial and Rice Research Centre, Agriculture Research Institute, Rajendranagar, Hyderabad during *Rabi 2019-20*. The artificial inoculation of conidial suspension (1x10^5conidia/ml) of *M. oryzae*(Local isolate of RARS and RRC) was sprayed uniformly over the 15-day-old seedlings.

Scoring was done at 10-15 days afterinoculation of blast culture depending on the spread of the infection using Standard Evaluation System (SES, IRRI, 1996). Based on leaf blast scores recorded, the genotypes were classified as resistant (0- 3), moderately resistant (3.1- 5) and susceptible (5.1- 9).

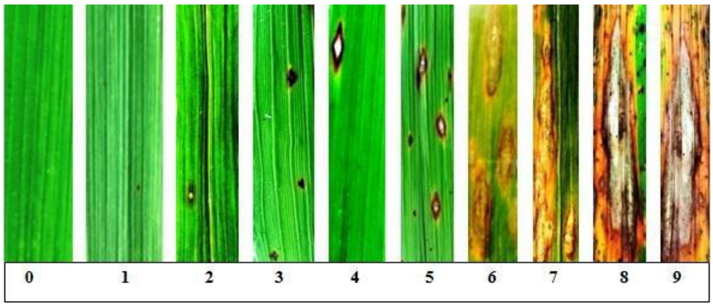

Plate 3 Photographic image for leaf blast disease scoring scale 0-9

Table 2 Scoring of parental lines, hybrids and checks evaluated for leaf blast incidence

S. No.	Hybrids	RARS, Polasa	ARI, Rajendranagar	Disease Reaction
	Parental lines			
1	JMS 13B	3	3	R
2	CMS 23B	3	3	R
3	CMS 46B	3	5	MR
4	CMS 59B	5	5	MR
5	RNR 26085	3	3	R
6	ZGY 1	3	3	R
7	TP 30022	3	5	MR
8	TP 30211	3	3	R
9	RNR 2354	1	1	R
10	MTU 1153	5	5	MR
11	RNR 28359	3	3	R
12	RNR 28411	1	0	R
13	MTU 1260	3	5	MR
14	RNR 21571	1	1	R
15	RNR 28361	5	3	MR
16	RNR 28344	5	5	MR
17	IRTON 270	5	3	MR
18	IR 72	1	0	R
19	JGL 35126	3	3	R
20	JGL 18047	3	5	MR
21	JGL 35047	1	1	R
22	JGL 34551	3	3	R
23	JGL 33508	3	5	MR
24	JGL 34452	3	3	R
	Hybrids			
25	JMS 13A × RNR 26085	3	1	R
26	JMS 13A × ZGY 1	3	1	R
27	JMS 13A × TP 30022	5	3	MR
28	JMS 13A × TP 30211	3	1	R
29	JMS 13A × RNR 2354	1	1	R
30	JMS 13A × MTU 1153	3	3	R
31	JMS 13A × RNR 28359	0	0	R

32	JMS 13A × RNR 28411	3	3	R
33	JMS 13A × MTU 1260	7	5	S
34	JMS 13A × RNR 21571	1	0	R
35	JMS 13A × RNR 28361	3	3	R
36	JMS 13A × RNR 28344	5	3	MR
37	JMS 13A × IRTON 270	3	1	R
38	JMS 13A × IR 72	1	1	R
39	JMS 13A × JGL 35126	3	1	R
40	JMS 13A × JGL 18047	1	1	R
41	JMS 13A × JGL 35047	1	0	R
42	JMS 13A × JGL 34551	3	3	R
43	JMS 13A × JGL 33508	3	5	MR
44	JMS 13A × JGL 34452	3	3	R
45	CMS 23A × RNR 26085	1	1	R
46	CMS 23A × ZGY 1	3	3	R
47	CMS 23A × TP 30022	5	3	MR
48	CMS 23A × TP 30211	1	1	R
49	CMS 23A × RNR 2354	3	3	R
50	CMS 23A × MTU 1153	5	3	MR
51	CMS 23A × RNR 28359	3	3	R
52	CMS 23A × RNR 28411	1	3	R
53	CMS 23A × MTU 1260	7	5	S
54	CMS 23A × RNR 21571	1	1	R
55	CMS 23A × RNR 28361	3	3	R
56	CMS 23A × RNR 28344	5	3	MR
57	CMS 23A × IRTON 270	5	3	MR
58	CMS 23A × IR 72	1	1	R
59	CMS 23A × JGL 35126	1	1	R
60	CMS 23A × JGL 18047	3	1	R
61	CMS 23A × JGL 35047	0	1	R
62	CMS 23A × JGL 34551	1	1	R
63	CMS 23A × JGL 33508	7	5	S
64	CMS 23A × JGL 34452	0	1	R
65	CMS 46A × RNR 26085	1	1	R
66	CMS 46A × ZGY 1	3	3	R
67	CMS 46A × TP 30022	7	7	S
68	CMS 46A × TP 30211	3	3	R
69	CMS 46A × RNR 2354	1	0	R
70	CMS 46A × MTU 1153	5	7	S
71	CMS 46A × RNR 28359	0	1	R
72	CMS 46A × RNR 28411	3	3	R
73	CMS 46A × MTU 1260	7	5	S
74	CMS 46A × RNR 21571	1	3	R
75	CMS 46A × RNR 28361	3	1	R
76	CMS 46A × RNR 28344	5	5	MR
77	CMS 46A × IRTON 270	3	1	R
78	CMS 46A × IR 72	1	0	R
79	CMS 46A × JGL 35126	3	1	R
80	CMS 46A × JGL 18047	3	3	R
81	CMS 46A × JGL 35047	1	1	R
82	CMS 46A × JGL 34551	3	0	R
83	CMS 46A × JGL 33508	7	5	S
84	CMS 46A × JGL 34452	1	0	R
85	CMS 59A × RNR 26085	1	0	R
86	CMS 59A × ZGY 1	1	3	R
87	CMS 59A × TP 30022	5	5	MR
88	CMS 59A × TP 30211	3	3	R
89	CMS 59A × RNR 2354	1	1	R
90	CMS 59A × MTU 1153	7	5	S
91	CMS 59A × RNR 28359	1	1	R
92	CMS 59A × RNR 28411	0	1	R
93	CMS 59A × MTU 1260	5	5	MR
94	CMS 59A × RNR 21571	1	1	R
95	CMS 59A × RNR 28361	3	2	R
96	CMS 59A × RNR 28344	7	7	S

97	CMS 59A × IRTON 270	3	3	R
98	CMS 59A × IR 72	0	1	R
99	CMS 59A × JGL 35126	3	3	R
100	CMS 59A × JGL 18047	3	3	R
101	CMS 59A × JGL 35047	1	1	R
102	CMS 59A × JGL 34551	3	0	R
103	CMS 59A × JGL 33508	7	9	S
104	CMS 59A × JGL 34452	3	5	MR
	Checks			
105	**TN-1**	9	9	S
106	US 314	3	3	R

R: Resistant; MR: Moderatelyresistant; S: Susceptible.

Based on disease score (IRRI-SES, 2013), out of 104 entries 73 entries were identified as resistant (R), 21 lines were moderately resistant (MR) whereas10 lines identified as susceptible. Similar findings was reported by earlier researchers viz., Dar *et al.,* (2015), Srijan*et al.,* (2015), Hosagoudar and Jairamamadabade (2017), VinayakTuraidar*et al.,* (2017) and Acharya*et al.,* (2019) for leaf blast resistance. The check TN1 was found to be highly susceptible and US 314 was resistant.

Plate 4 Field photo of uniform blast nursery (UBN)

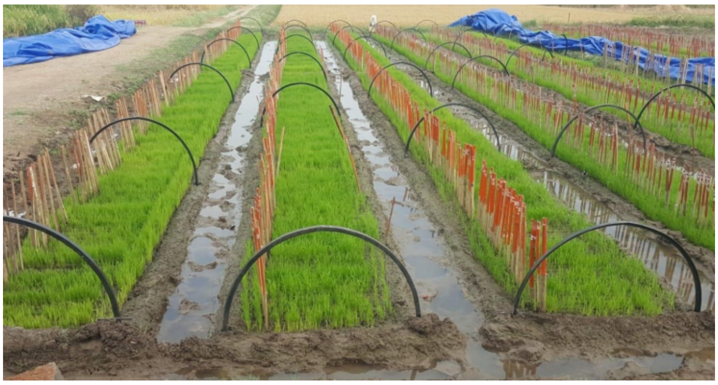

Plate 5Recording of blast score for parents, hybrids and checks

Susceptible check ***Resistant check***

Plate 5.1 incidence of leaf blast on susceptible and resistant checks

Summary and conclusions

The present investigation, "Development of hybrids resistant to cold and leaf blast in rice (Oryza sativa L.)," aimed to identify blast and cold-resistant hybrids. During the kharif season of 2019, 20 restorer lines and 4 cytoplasmic male sterile lines were selected, and 80 hybrids were developed. These hybrids, along with parental lines and suitable checks, were evaluated for cold stress and leaf blast at RARS, Jagtial, and ARI, Rajendranagar, during the rabi season of 2019-20.

With respect to the yellowing score (Jagtial and Rajendranagar), 19 hybrids recorded a 0-1 score, indicating a strongly tolerant reaction. 55 hybrids recorded a 2-3 score, indicating a tolerant reaction, and 6 hybrids recorded a 4-5 score, indicating a moderately tolerant reaction. Except for two testers, all the parents recorded a tolerant reaction.

Pooled data from cold screening showed that out of 104 lines, 20 lines were strongly tolerant (ST), 76 lines were tolerant (T), and 8 lines were moderately tolerant. None of the lines, except the susceptible checks, recorded sensitive or highly sensitive reactions.

Out of 104 entries screened for blast, 73 entries were identified as resistant (R), 21 lines were moderately resistant (MR), and 10 lines were identified as susceptible. The check TN1 was found to be highly susceptible, and US 314 was resistant (IRRI-SES, 2013).

Based on cold and blast scoring data, among the 20 restorers, 10 restorer lines showed tolerance to cold and resistance to leaf blast. These 10 restorer lines, namely RNR 26085, ZGY 1, RNR 2354, RNR 28359, RNR 28411, RNR 21571, IR 72, JGL 35126, JGL 35047, and JGL 34551, were selected and further utilized for combining ability, heterosis, and stability studies.

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