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Management of bakanae disease of rice caused by *Fusarium moniliforme*

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ABSTRACT

Roving survey of paddy (*Oryza sativa* L.) growing areas of Haryana indicated that the incidence of bakanae caused by *Fusarium moniliforme* Sheld. has increased considerably since its first record during *kharif* 1988. It has attained the status of major disease particularly in scented varieties of rice in the state. The disease incidence was significantly low when carbendazim treated and untreated seeds were sown under dry condition compared to conventional method of sowing sprouted seeds in puddled beds. However, in both the seed treatment methods, i.e. dry seed treatment and seed soaking in carbendazim solution at 1 and 2 g/kg seed, the disease was suppressed considerably. Bakanae incidence reduced drastically when paddy nursery was uprooted in standing water compared to uprooting of nursery in *vattar* condition. In addition to seed treatment, sand mix application of carbendazim in nursery beds at 1 g/m^2 seven days before uprooting of seedlings and as seedling dip in 0.1 per cent carbendazim solution for 3 hours before transplanting curtailed the bakanae incidence in transplanted crop. Foliar application of carbendazim at flowering stage reduced the grain infection of *F. moniliforme* from 73.9 to 35.0 percent. Out of 192 scented rice genotypes, 11 genotypes namely HKR 96-561, HKR 96-565, HKR 07-40, HKR 07-53, HKR 08-13, HKR 08-21, HKR 08-22, MAUB 2009-1, PAU 3456-46-6-1-1 and PNR 600, RDN 01-2-10-9 were found highly resistant while 38 genotypes proved moderately resistant. The remaining genotypes were moderately susceptible to highly susceptible.

Key words : Bakanae, Disease management, *Fusarium moniliforme*, Rice

Bakanae caused by *Fusarium moniliforme* Sheld. [teleomorph: *Gibberella fujikuroi* (Saw.) Wr.] is one of the important diseases of rice occurring throughout rice (*Oryza sativa* L.) growing regions of the world (Ram Singh and Sunder 2012). It is known to cause around 15 per cent loss in Uttar Pradesh and Asom states of India (Pavgi and Singh 1964, Rathaiah *et al*. 1991). In Haryana, bakanae has attained the status of a major disease after its first record since *kharif* 1988 particularly on scented tall varieties (Dodan *et al*. 1997). A highly positive correlation (r = 0.999) has been established between disease incidence and loss in grain yield of paddy (Sunder *et al*. 1997).

F. moniliforme is primarily a seed-borne pathogen which infects the seedlings at the time of germination or at an early growth stage (Ou 1985). Injured roots have been reported to serve as potential entry source of *Fusarium* spp. in different crops. In rice, injury to the roots mainly occurs during nursery uprooting depending upon the soil moisture. Some fungicides particularly the organomercurials and benzimidazoles have been reported to be effective in suppressing the fungal growth *in vitro* and bakanae incidence in field (Kauraw 1981, Sunder *et al*. 1998). Continuous attempts are needed to identify new sources of resistance against bakanae and effective chemicals for its management. The present study was undertaken to record the incidence of bakanae in different rice varieties cultivated in Haryana, to study the role of methods of nursery raising and field condition during nursery uprooting on disease incidence, and to evaluate the effectiveness of fungicide as seed treatment, nursery application and seedling dip in addition to screening of rice genotypes for resistance against the pathogen.

MATERIALS AND METHODS

To record the incidence and severity of bakanae in paddy growing areas of Haryana, roving surveys were conducted twice to thrice at maximum tillering to dough stage from k*harif* 1983 to 2012. The observations were recorded in terms of per cent infected plants after every 8-10 kilometer following Anonymous (1980). The disease incidence of all the locations over the years was pooled and the disease showing an average score of 0, 0.1 to 1, 1.1 to 3, 3.1 to 5 and above 5 was designated as - (not recorded), *(very low), ** (low), *** (moderate) and **** (severe), respectively.

A field trial was conducted during *kharif* 2007 and 2008

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at CCSHAU Rice Research Station, Kaul (29º 51' 29.5″ N, 76º 39' 24.3″ E and 230.7m AMSL in sub-tropical region of North-West India) to evaluate the efficacy of carbendazim (Bavistin 50 WP) as seed dresser with two different methods of seed treatment against bakanae disease of rice. Infected grains of a highly susceptible scented rice cultivar CSR 30 were treated with carbendazim at 1 g and 2 g formulated product/kg seed as dry seed treatment and seed soaking in fungicidal suspension for 24 hr. The soaked treated and untreated seeds were sprouted under wet gunny bags and sown in puddled beds of 5 × 1 m for each treatment while the dry counterparts were sown in dry beds and watered after sowing. Thirty days old seedlings of both the sets were uprooted at *vattar* condition (workable dry condition) and transplanted in randomized block design (RBD) with three replications in 3 × 2 m plots at 20 × 15 cm spacing. The crop was raised following recommended agronomic practices. The observations on disease incidence were recorded by counting bakanae infected and healthy plants in each plot 21 days after transplanting and per cent disease incidence was calculated. The grain yield was recorded at maturity and converted into kg/ha.

To study the role of soil conditions at the time of nursery uprooting, a field trial was laid out during *kharif* 2008, 2009 and 2010 using two susceptible cultivars CSR 30 and Pusa Basmati 1121. The infected seeds of both the cultivars were sprouted and sown in 5 × 1 m puddled beds in two sets. The nursery of one set was uprooted at *vattar* condition while that of another set in standing water. Thirty days old seedlings from both the sets were transplanted in 3 × 2 m plots at 20 × 15 cm spacing in RBD with five replications.

Besides seed treatment, the efficacy of carbendazim was also evaluated as nursery application, seedling dip and foliar spray alone and in combinations against bakanae and grain infection of *F. moniliforme*. For this purpose, a field trial was conducted during *kharif* 2010 and 2011. Nursery for individual treatment was raised from infected seed of Pusa Basmati 1121. Thirty days old seedlings of each treatment were transplanted in 3 × 2 m plots at 20 × 15 cm spacing in a RBD with three replications. The observations on disease incidence and grain yield of paddy in above mentioned field trials were recorded as described under evaluation of fungicides as seed treatment. The grain infection by *F. moniliforme* in different treatments was studied on a selective medium as described under Sunder and Satyavir (1998).

To identify the sources of resistance to bakanae, a collection of 192 scented rice genotypes was screened under artificial inoculation conditions during *kharif* 2010. A pathogenic isolate of *F. moniliforme* was grown on PDA plates at 30±1° C for 15 days. The conidia were harvested in sterilized distilled water with gentle brushing and adjusted to a concentration of 2×10^7 conidia/ml for inoculation. Thirty days old seedlings of each genotype were uprooted under *vattar* condition, washed and inoculated by dipping their roots in freshly prepared inoculum suspension for two hours. Inoculated seedlings were transplanted in two rows of 3 m length at 20 × 15 cm spacing in puddled field having practically no standing water to avoid washing of inoculum. The field was irrigated 24 hours after transplanting and the crop was raised following recommended agronomic practices. The observations on disease incidence were recorded 21 days after transplanting and the genotypes showing a disease incidence of 0, <1, 1-5, 5.1-25, 25.1-50 and above 50 per cent were rated as 0 (highly resistant), 1 (resistant), 3 (moderately resistant), 5 (moderately susceptible), 7 (susceptible) and 9 (highly susceptible), respectively. The genotypes showing resistance (disease score 0-3) during *kharif* 2010 were retested during *kharif* 2011 to confirm their reaction.

RESULTS AND DISCUSSION

Roving survey of paddy growing districts of Haryana revealed that bakanae disease of rice, first recorded during *kharif* 1988, had attained the status of a major disease of scented tall varieties in Haryana. The disease was considered to be introduced from Punjab through infected paddy seed as it was prevalent in Punjab prior to 1988 and was recorded in Haryana for the first time at farmer's field in a paddy cultivar PR 109 which was commonly grown in Punjab at that time. The disease, though recorded on both scented and non-scented cultivars, was more damaging in scented varieties particularly Taraori Basmati, CSR 30 and Pusa Basmati 1121. Amongst non-scented varieties, the disease was found to be more damaging in Haryana Gaurav and PR 109. A considerable increase in disease incidence during 1989 and 1991 leading to the build up of inoculum in seed and soil and tremendous increase in area under highly susceptible scented tall cultivars particularly Taraori Basmati (192 thousand ha during 1991-92 to 300 thousand ha during 1992-93) resulted in epiphytotics during *kharif* 1992. In few fields where farmers used their own infected and untreated seed, the disease incidence was very high (70-80%) leading to ploughing up and re-transplanting of the paddy. During *kharif* 1994 to 2004, the bakanae incidence declined significantly and the disease was recorded in low intensity. However, the disease intensity increased after *kharif* 2008 which might be attributed

Table 1 Intensity of foot rot and bakanae during *kharif* 1983 to 2012

Years	Disease intensity
1983-87	
1988-94[a]	****
1995-99	**
2000-04	**
2005-08	***
2009-12	***

**Low, ***Moderate, ****Severe

Table 2 Effect of seed treatment (ST) method on bakanae incidence and grain yield of paddy variety CSR 30

Chemical	*Kharif* 2007			*Kharif* 2008			Mean of *Kharif* 2007 & 2008	
	Dry ST	Seed soaking	Mean	Dry ST	Seed soaking	Mean	Dry ST	Seed soaking
Carbendazim 1 g/kg	1.8*	5.5	3.6	3.1	7.9	5.5	2.5	6.7
	(4083)**	(3833)	(3958)	(3875)	(3667)	(3771)	(3979)	(3750)
Carbendazim 2 g/kg	1.0	3.0	2.0	1.7	4.6	3.2	1.3	3.8
	(4167)	(4000)	(4084)	(4042)	(3750)	(3896)	(4104)	(3875)
Check	11.7	32.4	22.0	16.2	39.3	27.7	13.9	35.8
	(3708)	(2833)	(3271)	(3500)	(2583)	(3042)	(3604)	(2708)
Mean	4.8	13.6		7.0	17.3		5.9	15.4
	(3986)	(3555)		(3806)	(3333)		(3896)	(3444)
CD (P=0.05) for		*Kharif* 2007			*Kharif* 2008			
Method of ST		2.3 (213)			2.0 (186)			
Amount of carbendazim		2.8 (261)			2.4 (228)			
Interaction		3.9 (368)			3.5 (322)			

*Bakanae incidence (%);**Grain yield (kg/ha)

to a significant increase in area under cultivation of highly susceptible scented varieties (432 thousand ha in 2007-08 to 810 thousand ha in 2011-12) particularly Pusa Basmati 1121 and prevalence of favourable environmental conditions for disease development (Table 1).

In Haryana, the rice crop is mainly cultivated by transplanting method. However, direct sowing of rice is also gaining momentum in the state. The paddy nursery is raised by sowing sprouted or unsprouted seed after seed soaking in fungicidal suspension or dry seed treatment. Broadcasting of sprouted grains (treated or untreated) in puddled beds is a common practice for raising paddy nursery. In present study, the modifications in methods of seed treatment and nursery raising affected bakanae incidence in transplanted crop. Application of carbendazim both as dry seed treatment and seed soaking in fungicidal suspension reduced the bakanae incidence significantly in both the years of testing (Table 2). However, the fungicidal dosage had no significant effect on disease incidence. Earlier researchers have also reported the effectiveness of carbendazim against bakanae (Iguchi and Takeuchi 1988, Dodan *et al.* 1994). The disease incidence was considerably low when treated and untreated seeds were sown under dry condition compared to conventional method of sowing sprouted seeds in puddled beds. On mean basis, the reduction in bakanae incidence was nearly 60% in former method of nursery raising, i.e. dry seed nursery. It might be attributed to the fact that repeated turning over of seed for thorough mixing and sprinkling of water on gunny bags for uniform sprouting facilitates the infection of pathogen to the healthy seeds during seed sprouting in conventional method of nursery raising. The grain yield in different treatments corresponded with the increase or decrease of disease in these treatments.

Field condition at the time of nursery uprooting had significant effect on bakanae incidence in both the cultivars (Table 3). The disease incidence reduced considerably in plots where nursery was uprooted in standing water. On mean basis, the bakanae incidence was 9.4 and 23.0 per cent in CSR 30 and Pusa Basmati 1121, respectively in plots planted with nursery uprooted in standing water as against 28.8 and 58.1% in plots planted with nursery uprooted under *vattar* condition. The higher disease incidence under *vattar* condition might be attributed to facilitation of pathogen entry through injured roots which is more in this condition of nursery uprooting. The mean disease reduction varied between 60.1-70.4% in CSR 30 and 57.5-63.2% in Pusa Basmati 1121 during three years of testing in plots planted with nursery uprooted in standing water as against those planted with nursery uprooted under *vattar* condition. The interaction between variety and field condition during nursery uprooting was found to be significant.

Beside seed treatment, nursery application of carbendazim as sand mix broadcast at 1 g/m^2 seven days before uprooting and as seedling dip in 0.1% carbendazim solution for three hours proved quite effective in reducing the incidence of bakanae (Table 4). On mean basis, seed soaking, nursery application and seedling dip in carbendazim solution reduced the bakanae incidence from 42.4% to 4.7-11.3% along with a significant increase in grain yield of paddy cultivar Pusa Basmati 1121. The disease control provided by nursery application of carbendazim and as seedling dip before transplanting was 79.5 and 73.3%, respectively. Bagga and Sharma (2006) have also observed the effectiveness of carbendazim and benomyl as seedling dip treatment. Seed soaking in carbendazim solution followed by its nursery application or seedling dip was at par with seed treatment alone. Foliar spray of carbendazim at flowering stage reduced grain infection by the pathogen significantly. It varied between 28.9-41.1% in sprayed plots as against 66.7-81.1% in plots having no spray application (Table 4).

Table 3 Effect of field condition at the time of nursery uprooting on bakanae incidence and grain yield of paddy cultivars CSR 30 and Pusa Basmati 1121

Variety	Bakanae incidence (%)											
	Vattar condition				Standing water				Reduction in bakanae and increase in grain yield (%) over *Vattar* condition			
	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean
CSR 30	24.3*	30.4	31.8	28.8	7.2	8.2	12.7	9.4	70.4	73.0	60.1	67.8
	3 167**	2 667	1 767	2 534	3 833	3 533	2 267	3 211	21.0	32.5	28.3	27.3
Pusa Basmati- 1121	53.2	67.1	54.0	58.1	19.6	28.5	20.9	23.0	63.2	57.5	61.3	60.7
	2 433	1 700	1 500	1 878	4 200	3 600	2 600	3 467	72.6	52.8	73.3	66.2
Mean	38.7	48.8	42.9	43.5	13.4	18.4	16.8	16.2	66.8	65.3	60.7	
	2 800	2 183	1 633	2 205	4 017	3 567	2 433	3 339	43.5	63.4	49.0	
CD 5% for	*Variety*				*Field condition*				*Variety* × *field condition*			
Kharif 2008	2.9* (N.S.)**				2.9 (211)				4.1 (299)			
Kharif 2009	3.0 (206)				3.0 (206)				4.2 (291)			
Kharif 2010	3.3 (N.S.)				3.3 (169)				4.7 (238)			

*Bakanae incidence (%);**Grain yield (kg/ha)

Table 4 Effect of different treatments on bakanae incidence, grain yield and recovery of *Fusarium moniliforme* from grains of Pusa Basmati 1121

Treatment*	Bakanae (%)			Grain yield (kg/ha)			Grain yielding *F. moniliforme* (%)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
SSC	3.3	6.0	4.7	2 444	4 722	3 583	74.4	48.9	61.7
NAC	7.0	10.3	8.7	2 333	4 445	3 389	75.6	52.2	63.9
SDC	8.0	14.5	11.3	2 278	4 278	3 278	73.3	51.1	62.2
FSC	53.6	29.8	41.7	1 389	3 500	2 445	41.1	28.9	35.0
SSC+NAC	1.7	4.5	3.1	2 556	4 833	3 695	65.6	50.0	57.8
SSC+SDC	1.3	5.3	3.3	2 444	4 722	3 583	67.8	52.2	60.0
SSC+FSC	3.5	5.8	4.7	2 389	4 778	3 584	38.9	26.7	32.8
NAC+FSC	8.2	10.2	9.2	2 333	4 445	3 389	37.8	24.5	31.1
SDC+FSC	6.7	15.0	10.9	2 278	4 222	3 250	40.0	26.7	33.3
SSC+NAC+FSC	2.0	4.2	3.1	2 556	4 833	3 695	40.0	22.3	31.2
SSC+SDC+FSC	1.5	4.8	3.2	2 500	4 778	3 639	35.6	22.3	28.9
Check	54.7	30.0	42.4	1 333	3 500	2 417	81.1	66.7	73.9
CD (P=0.05)	5.2	3.3	4.3	230	379	305	8.6	4.6	6.6

*SSC: Seed soaking in carbendazim solution (1 g/l water/ kg seed) for 24 hr, NAC: Nursery application of carbendazim (1 g/m^2) 7 days before uprooting, SDC: Seedlings dip in 0.1% carbendazim solution for 3hr, FSC: Foliar spray of 0.1% carbendazim at flowering stage

Table 5 Rice genotypes found resistant to bakanae

Disease score	Genotypes
0 (HR)	HKR 96-561, HKR 96-565, HKR 07-40, HKR 07-53, HKR 08-13, HKR 08-21, HKR 08-22, MAUB 2009-1, PAU 3456-46-6-1-1, PNR 600, RDN 01-2-10-9
1 (R)	Nil
3 (MR)	HKR 90-403, HKR 92-401, HKR 92-447, HKR 93-401, HKR 93-402, HKR 94-414, HKR 94-415, HKR 94-417, HKR 94-418, HKR 94-419, HKR 94-416, HKR 95-435, HKR 95-436, HKR 95-449, HKR 95-514, HKR 95-515, HKR 96-437, HKR 96-501, HKR 96-523, HKR 96-538, HKR 96-539, HKR 96-540, HKR 96-574, HKR 07-34, HKR 07-35, HKR 07-36, HKR 07-50, HKR 08-5, HKR 08-9, HKR 08-11, HKR 08-14, HKR 08-16, HKR 08-17, HKR 08-43, HUBR 10-9, NDR 6271, RP 3138-60-9-6-6, UPR 3385-20-1-2

On mean basis, foliar spray of carbendazim reduced the grain infection from 73.9% to 35.0%. In earlier studies, foliar application of benomyl and carbendazim (Hajra *et al.* 1994, Sasaki 1987) have been reported to curtail the seed-borne inoculum of *F. moniliforme* and the disease spread.

Out of 192 scented rice genotypes evaluated against bakanae during *kharif* 2010 and 2011, 11 genotypes, viz. HKR 96-561, HKR 96-565, HKR 07-40, HKR 07-53, HKR 08-13, HKR 08-21, HKR 08-22, MAUB 2009-1, PAU 3456-46-6-1-1 and PNR 600, RDN 01-2-10-9 were found highly resistant while 38 genotypes showed moderate resistance. Of the remaining genotypes, 97, 39 and 7 proved moderately susceptible, susceptible and highly susceptible, respectively (Table 5). The genotypes HKR 04-487, HKR 05-436, HKR 05-476, HKR 07-2 and HKR 07-3 exhibiting moderate susceptibility to bakanae in present study have been reported to possess resistance to both leaf and neck blast phases (Singh *et al.* 2010, 2011). The scented cultivars namely Basmati 370, CSR 30, Haryana Basmati 1, Pusa Basmati 1, Pusa Basmati 1121 and Taraori Basmati commonly grown in Haryana were found moderately susceptible to highly susceptible.

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