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Effect of system of rice cultivation on sheath rot disease and traits associated with grain yield under natural disease incidence in rice RIL's

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Abstract
One thousand and ninety four recombinant inbred lines derived from BPT-5204 × HP-14 cross were evaluated for sheath rot disease incidence under field conditions under aerobic and wetland transplanted situation. The population exhibited significant genetic variability among the RIL's in both systems of rice cultivation. Response of the disease in both conditions was non-significant indicating that influence of planting system did not make any significant difference for this disease. Transgressive segregants were observed for yield attributing traits but not for sheath rot resistance. RILs HPR-1270, HPR-1416, HPR-212, HPR-260, HPR-1506, HPR-1407, HPR-1380 and HPR-312 in aerobic system and HPR-285, HPR-2129, HPR-978, HPR-702, HPR-94-2, and HPR-1514 in wetland system were found superior for both grain yield and sheath rot resistance. These genotypes could be evaluated further in large scale field trials for developing resistance varieties with superior grain yield.

Key words: recombinant inbred lines, sheath rot disease, aerobic rice, wetland rice, transgressants.

Introduction

Rice is staple food for more than half of the world population. Sustainable rice production is threatened by both abiotic and biotic stresses (Khush, 2005). Among biotic stress, drought is major constraints for sustainable rice production (Tuong and Bouman, 2003). Aerobic rice is considered as alternate method for sustainable rice production in view of water shortage for puddled rice planting. Aerobic method involves direct seeding with surface irrigations in aerated soil (aerobic) at regular intervals comparable to other cereals like maize and irrigated ragi (Venkataravana and Hittalmani, 1999; Hittalmani, 2007a, 2007b, Grassi *et al.*, 2009; Rajkumar *et al.*, 2009; Gandhi *et al*, 2012 and Nei *et al.*, 2012). Among biotic stresses, sheath rot disease of rice caused by *Sarocladium oryzae* [(Sawada) W. Gams & D. Hawksw] is emerging as the major disease in rice, affecting the crop in almost all rice-growing ecosystems. It is a serious menace to rice cultivation, causing yield lossess of 3–85 *per cent* depending upon the disease severity (Chen, 1957, Amin *et al*, 1974, Chakravarthy and Biswas, 1978). Severe infection leads to 100 *per cent* seed sterility and complete suppression of panicle exertion (Raina and Singh, 1980). Dwarf and semi dwarf *indica* cultivars are more prone to sheath rot disease compared to tall statured and *japonica* cultivars (Hittalmani *et al.*, 2000 and Srinivasachary *et al.*, 2002).

Aerobic rice is associated with beneficial rhizosphere microbes, inhibits growth and development of rice pathogens (Ren *et al.*, 2008; Fillipi *et al.*, 2012; Spence *et al.*, 2014 and Rego *et al.*, 2014) and promotes plant growth (Panhwar *et al.*, 2012). However, sheath rot disease causes considerable qualitative and quantitative yield loss in both aerobic and wetland rice. Therefore, the present investigation was undertaken to study the effect of aerobic and wetland system of rice cultivation on incidence and severity of sheath rot disease in recombinant inbred lines derived from BPT-5204 × HP-14 cross under two types of paddy cultivation.

Materials and Methods

Plant material

Recombinant Inbred Lines (RILs) derived from BPT-5204 (susceptible to sheath rot disease used as female parent) and HP-14 (resistant to sheath rot disease used as male parent). F_2 plants were advanced to subsequent generation by single seed descent method and recombinant inbred lines of F_9 generation (Shashidhara, 2012; Banu *et al*, 2011 and Uday, 2013) were used in the present investigation.

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Experimental details

The study included 1094 recombinant inbred lines, parental lines (BPT-5204 and HP-14) aerobic rice checks MAS-26 and MAS-946-1; and IR-64 as check variety for irrigated rice. Evaluation for sheath rot disease response was done in field condition during *kharif* season, 2013 with natural innoculum. The experiments were conducted in randomized complete block design with two replications in aerobic condition with directed seeding and surface irrigation was provided twice a week. The second experiment with two replications was in transplanted condition with 3" standing water throughout the crop growth period. The cultural operations for wetland and aerobic systems were followed as per recommended package of practices.

Observations recorded

Observations were recorded from middle five plants and mean values were used for data analysis. Data collection was done at days to 50 *per cent* flowering, plant height (cm) at maturity, productive tillers per plant and panicle length (cm). Panicle exertion (cm) was recorded as positive value in fully exerted varieties and negative for partially exerted varieties. Grain yield and straw yield per plant (g) was recorded from mean of five plants in each entry.

Sheaths rot disease scoring

One thousand and ninety four recombinant inbred lines were evaluated for sheath rot disease using three parameters *viz.*, sheath rot lesion length (cm), sheath rot disease incidence (SES) scores (IRRI, 2002) and modified sheath rot disease severity score (in-house standardization,). Disease incidence and severity scores were used to estimate the *per cent* disease index (PDI), arc sine transformed values were used for statistical analysis. Transgressive segregants (expressed in per cent) were estimated for each traits as proprotion of recombinant inbred lines surpassing parental limit.

Statistical analysis

Observation of individual charcters was carried out using mean values of randomly selected five plants from each genotypes and for each replication. The genotypic and phenotypic coefficients of variation (Burton and Devane, 1953), heritability and genetic advance as per cent mean (Hanson *et al.,* 1956 and Johnson *et al.,* 1955) were estimated separately for aerobic and wetland rice. Significance in mean performances of each traits between aerobic and wetland rice was tested using't test assuming unequal variances' (Roy, 2000).

Results and Discussion

Availability of genetic variability is a pre requisite in selection and analysis of variance commonly is used to assess the significance of genetic variability among genotypes in plant breeding experiments. Significant mean sum of squares observed for sheath rot and yield attributing traits in RIL's under both aerobic and wetland conditions indicate the presence of wide range of genotypic variability (Table 1). Further partitioning of variances into genotypic and phenotypic components is required for estimation of heritability and genetic advance. Phenotypic and genotypic coefficient of variances is useful for comparison of variability of different characters or between different populations. Large difference between estimates of PCV and GCV suggest higher influence of environment in the manifestation of traits. Second degree statistics like GCV and PCV are useful for selection of desirable traits (Roy, 2000).

Large differences between GCV and PCV were observed for sheath rot disease attributing traits in both aerobic and wetland condition is indicating the manifold influence of environment in expression of traits. High GCV and PCV was observed for sheath rot lesion length (113.91 and 323.38), disease incidence (120.48 and 314.59) and severity (147.52 and 337.53) in aerobic system suggested high influence of environmental factors such as cool temperature and high relative humidity (Reddy *et al*., 1999 and Reddy *et al.,* 2001) or due to lower quantum of inoculum (Agrios, 2004). Similar trend was observed for sheath rot lesion length (113.60 and 323.38), disease incidence (107.28 and 299.75) and severity (121.16 and 316.10) in wetland condition.

Broad sense heritability measures proportion of genetic variability and useful for prediction of selection response, behaviour of traits during selection, population size for trait improvement and strategic planning of selection schemes. Low heritability was observed for sheath rot disease attributing traits such as sheath rot lesion length (0.12, 0.12), sheath rot (SES) incidence (0.15 and 0.13) and sheath rot severity scores (0.19 and 0.15) in aerobic and wetland conditions respectively. Therefore, larger population size and pedigree method of breeding with progeny test are useful identifying suitable resistant genotypes (Roy, 2000).

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Genetic advance or response to selection depends on heritability, selection intensity and phenotypic standard deviation, which includes both genetic and environmental variations. Low heritability with high genetic advance as per cent mean was observed for sheath rot disease attributing traits in aerobic and wetland conditions. Therefore, family selection with progeny test is found suitable for improvement of sheath rot disease resistance in rice (Roy, 2000).

Mean performances in wetland and aerobic rice

Mean performance of parental lines did not differ for response to sheath rot disease in aerobic and wetland conditions. Female parent BPT-5204 was highly susceptible to sheath rot disease and exhibited severe symptoms. Average lesion length of BPT-5204 was 10 and 8.3 cm under aerobic and wet land condition respectively. Male parents (HP-14) took no infection and possessed higher level of resistance.

Parental lines exhibited differences in performance for yield and yield attributing traits between aerobic and wetland conditions. Female parent BPT-5204 flowers early (91 days) and dwarf plant types (57.38 cm) in aerobic system as compared to wetland condition (took 97 days for flowering and recorded 75.50 cm plant height). Female parent produced more number of productive tillers in aerobic condition (22) as compared to wetland condition (11.20). Similarly, BPT-5204 recorded maximum panicle length (22.21 cm) in aerobic condition and high straw weight per plant (58.80 g), grain yield per plant (30.60 g) and biomass per plant (89.40) under wetland condition. Contrary to female parent, male parent was flowered early (90.50 days) and dwarf statured plant type (89.53 cm) in wetland condition as compared to aerobic condition (102 days for flowering with plant height of 109.10 cm). As observed in BPT-5204, HP-14 also produced more number of productive tillers in aerobic condition (13) as compared to wetland condition (7.50). Male parent HP-14 produced maximum straw yield per plant (25.90 g), biomass per plant (39.87 g) in aerobic system and longer panicle (20.50 cm) and grain yield per plant (14.97 g) in wetland condition.

Among RIL's, sheath rot lesion length, sheath rot incidence (SES) , and severity scores under both aerobic and wetland conditions did not differ significantly (Table 2). The experimental results showed that system of rice cultivation either in aerobic or wetland condition had no effect on sheath rot disease incidence or severity. Non-significance of sheath rot disease incidence and severity of disease under aerobic and wetland conditions suggests that both system of cultivation are suitable for screening of germplasm and breeding pool.

Significant differences were observed in mean performances of yield attributing traits between aerobic and wetland system. Mean performances of RIL's showed that recombinant inbred lines were flowered early (88.76 days) in wetland condition as compared to aerobic rice (97.68 days). Mean plant height of recombinant inbred lines was 89.53 cm in aerobic rice as compared to wetland rice (94.95 cm). Maximum number of productive tillers (11.38) and panicle length (18.59 cm) was observed in aerobic rice as compared to wetland rice (10.26 of productive per plant and 12.27 cm of panicle length). Mean grain yield (15.55 g), straw yield (33.14 g) and biomass per plant (48.69 g) of recombinant inbred lines were significantly high in aerobic rice cultivation as compared to wetland system.

Transgressive segregants

Transgressive segregants result from combination of alleles from both parents that have complementary gene effects dispersed between parents (Risenberg *et al.*, 1999). No transgressive segregants were observed for sheath rot disease resistance attributing traits suggesting that sheath rot disease resistance is contributed by male parent (Table 3). However, transgressive segregants were observed for most of the yield attributing traits indicating the contribution of genes by both parents. Transgressive segregants combined with many are rare for quantitative traits (Palmer, 1953).

Superior high yielding recombinant inbred lines combined with sheath rot disease resistance were indentified in both aerobic and wetland conditions (Table 4 and table 5). Under aerobic condition, HPR-1270, HPR-1416, HPR-212, HPR-260, HPR-1506, HPR-1407, HPR-1380 and HPR-312 were high yielding surpassing the better parent BPT-5204 for grain yield combined with sheath rot disease resistance attributing traits. HPR-260 recorded superior for grain yield with early flowering. Similarly, RIL's HPR-285, HPR-2129, HPR-978, HPR-702, HPr-94-2, and HPR-1514 were superior as compared to better parent BPT-5204 for grain yield, plant height, productive tillers and early in flowering combined with sheath rot disease resistance

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attributing traits under wetland condition. HPR-1-1 was found superior for productive tillers with early flowering and HPR-1506 for early flowering only as compared to better parent BPT-5204. HPR-1054 recorded superior panicle exertion as compared to better parent (HP-14). Transgressive segregants such as HPR-1270, HPR-1416, HPR-212, HPR-260, HPR-1506, HPR-1407, HPR-1380 and HPR-312 in aerobic system and HPR-285, HPR-2129, HPR-978, HPR-702, HPR-94-2, and HPR-1514 in wetland system were found superior for grain yield combined with sheath rot disease resistance. These genotypes could be evaluated further in large scale field trials for developing resistance varieties with superior grain yield.

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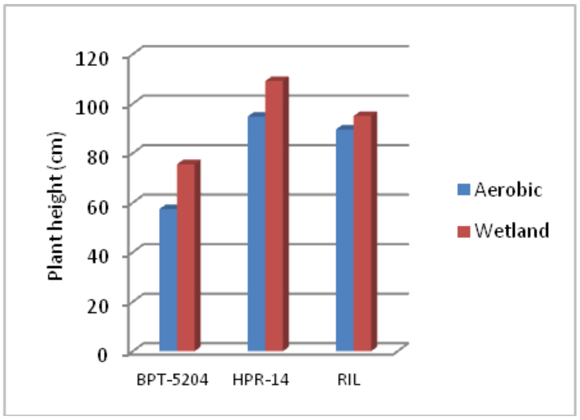
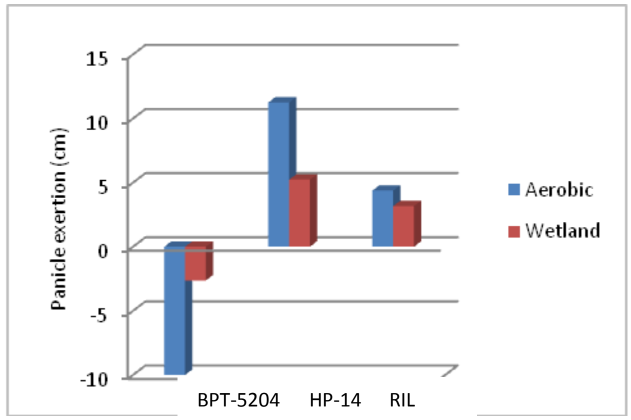
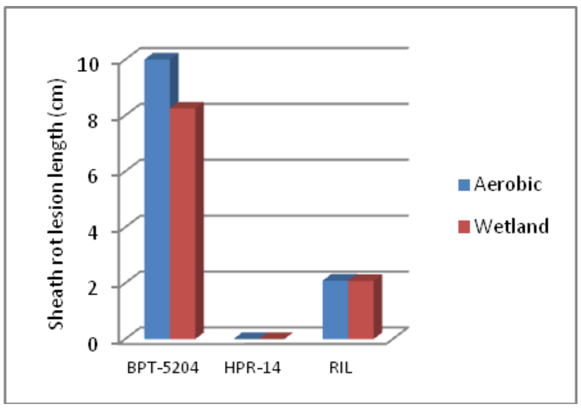


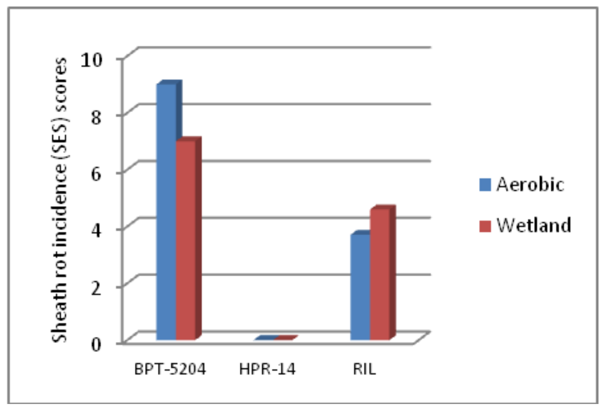
i. Plant height



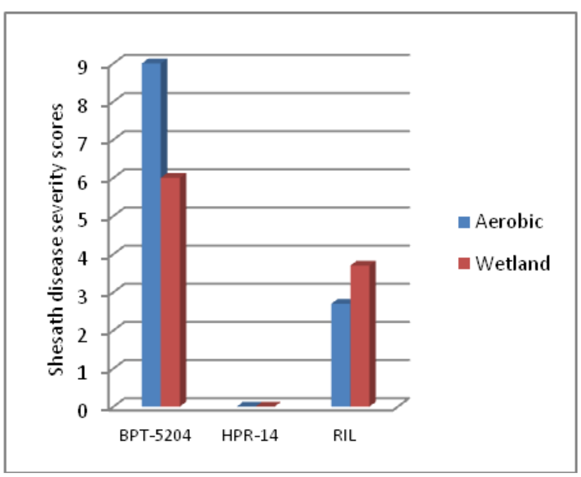
ii. Panicle exertion (cm)



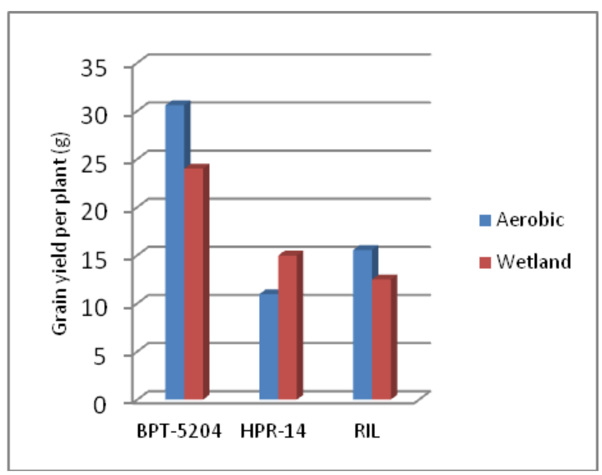
iii. Sheath rot lesion length (cm)



iv. Sheath rot disease incidence (SES) scores



v. Sheath rot severity scores



vi. Grain yield per plant (g)

Fig 1. Performance of parental lines (BPT-5204 and HP-14) and recombinant inbred lines for sheath rot disease and yield attributing traits in rice

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Table 1. Analysis of variance for disease attributing traits in RIL's derived from BPT-5204 × HP-14 along with parents and checks under aerobic and wetland conditions

Source	**PE**		**ShLL**		**ShR(SES)**		**ShR(S)**	
	A	W	A	W	A	W	A	W
Replication	10.57	17.35	17.47	28.39	504.71	693.50	238.85	637.17
Genotypes	88.2**	68.9**	51.50**	51.18**	389.54**	465.00**	301.77**	388.42**
Error	58.36	3.45	40.13	39.99	289.88	359.39	204.98	288.91

* significant @ 1 *per cent* level of significance and ** significant @ 5 *per cent* level of significance

ShLL	:	Sheath rot lesion length (cm)	ShR(SES)	:	Sheath rot incidence (SES) score
ShR(S)	:	Sheath rot severity (SES) score	ShB	:	Sheath blight severity (SES) score
BS	:	Brown leaf spot (SES) score	LB	:	Leaf blast (SES) scores
NB	:	Neck blast (SES) score			

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Table 2. Descriptive statistics for response to sheath rot disease resistance and yield attributing traits in 1094 RIL's derived from BPT-5204 × HP-14 cross under field condition in rice

							Range											
	BPT-5204		HPR-14		Mean		A		W		GCV		PCV		h^2		GAM	
Traits	A	W	A	W	A	W	Min	Max	Min	Max	A	W	A	W	A	W	A	W
A. Yield attributing traits																		
DFL	91.00	97.00	102.00	90.50	97.68**	88.76**	77.00	117.50	76.50	106.00	6.27	9.39	12.53	11.47	0.25	0.67	6.46	15.83
PH	57.38	75.50	94.75	109.10	89.53**	94.95**	48.20	116.50	48.63	143.87	18.82	23.35	23.69	30.33	0.63	0.59	30.81	37.02
PT	22.00	11.20	13.00	7.50	11.38**	10.26**	1.60	31.10	3.05	23.00	62.96	41.08	68.74	51.88	0.84	0.63	118.77	67.01
PL	16.60	22.21	17.50	20.50	18.59**	17.27**	13.20	26.93	9.50	23.78	12.40	12.07	18.68	22.18	0.44	0.30	16.96	13.53
SW	58.80	31.10	25.90	24.90	33.14**	26.07**	10.00	89.40	5.23	66.10	44.81	65.55	57.72	71.09	0.60	0.85	71.65	124.50
GY	30.60	24.00	10.96	14.97	15.55**	12.48**	2.75	39.00	2.61	32.90	52.39	63.52	66.26	70.28	0.63	0.82	85.33	118.29
BM	89.40	55.10	36.86	39.87	48.69**	38.55**	12.75	128.40	9.43	96.51	44.32	58.16	57.19	62.68	0.60	0.86	70.77	111.16
HI	0.34	0.44	0.30	0.38	0.32**	0.33**	0.09	0.56	0.11	0.57	25.11	41.00	29.73	48.12	0.71	0.73	43.68	71.98
B. Sheath rot disease attributing traits																		
PE	-10.00	-2.63	11.25	5.23	4.38**	3.17**	-10.00	14.90	-7.60	13.05	88.33	180.30	195.66	189.58	0.20	0.90	82.14	353.26
ShLL	10.00	8.25	0.00	0.00	2.09	2.08	0.00	10.17	0.00	10.17	113.91	113.60	323.38	324.20	0.12	0.12	82.65	82.00
ShR(SES)	20.00	18.33	0.00	0.00	3.71	4.60	0.00	20.00	0.00	22.59	120.48	107.28	314.59	299.75	0.15	0.13	95.06	79.10
ShR(S)	20.00	15.56	0.00	0.00	2.70	3.70	0.00	15.56	0.00	20.00	147.52	121.16	337.53	316.10	0.19	0.15	132.81	95.67

A	:	Aerobic	W	:	Wetland			
PH	:	Plant height (cm)	PE	:	Panicle exertion (cm)	ShR(SES)	:	Sheath rot disease incidence (SES) score
ShR(S)	:	Sheath rot severity score	ShLL	:	Sheath rot lesion length (cm)	PIT	:	Percent infected tillers (SES)
DI	:	Disease indices	GY	:	Grain yield/plant (g)			

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Table 3. Estimates of observed frequencies of transgressive segregants for traits attributing to sheath rot disease resistance and yield attributing traits in 1094 RIL's derived from BPT-5204 × HP-14 cross under aerobic and wetland conditions

Sl No	Traits	Aerobic		Wetland	
		Parental criteria	Observed frequencies (*per cent*)	Parental criteria	Observed frequencies (*per cent*)
A. Yield attributing traits					
1	Days to 50 *per cent* flowering	< BPT-5204	6.76	>BPT-5204	3.11
		>HP-14	17.92	<HPR-14	61.52
2	Plant height (cm)	<BPT-5204	0.55	<BPT-5204	10.33
		>HPR-14	31.44	>HPR-14	6.49
3	Productive tillers/plant	<BPT-5204	0.55	>BPT-5204	30.99
		> HP-14	31.44	<HPR-14	10.15
4	Panicle length (cm)	<BPT-5204	1.01	>BPT-5204	0.18
		> HP-14	68.83	<HPR-14	97.90
5	Panicle exertion (cm)	<BPT-5204	0.00	<BPT-5204	8.68
		>HPR-14	1.28	>HPR-14	21.57
6	Straw weight	>BPT-5204	1.19	>BPT-5204	26.33
		<HPR-14	18.83	<HPR-14	48.54
7	Grain yield/plant (g)	>BPT-5204	0.82	>BPT-5204	1.46
		<HPR-14	16.45	<HPR-14	74.04
8	Biomass	>BPT-5204	0.55	>BPT-5204	9.05
		<HPR-14	16.36	<HPR-14	58.68
9	Harvest index	>BPT-5204	28.15	>BPT-5204	8.14
		<HPR-14	30.80	<HPR-14	71.66
B. Sheath rot disease attributing traits					
1	Sheath rot lesion length (cm)	>BPT-5204	0.09	>BPT-5204	3.93
		<HPR-14	0.00	<HPR-14	0.00
2	Sheath rot incidence (SES scores)	>BPT-5204	0.00	>BPT-5204	3.75
		<HPR-14	0.00	<HPR-14	0.00
3	Sheath rot severity scores	>BPT-5204	0.00	>BPT-5204	2.83
		<HPR-14	0.00	<HPR-14	0.09

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Table 4: Transgressive segregants for grain yield combined with sheath rot disease resistance and their parents for sheath rot disease under aerobic condition in natural disease screening in rice during *kharif* 2013

Sl No	RIL's	GY	Grain yield related traits			Sheath rot disease related traits					
			DFL	PH	PT	PE	ShLL	ShR(SES)	ShR(S)	DI-1	DI-2
1	HPR-1270	**36.8**	96.0	99.5	17.6	7.0	0.0	0	0	0	0
2	HPR-1416	**33.4**	107.5	104.8	14.1	3.4	0.0	0	0	0	0
3	HPR-212	**32.2**	100.0	94.0	16.1	5.4	0.0	0	0	0	0
4	HPR-260	**31.9**	89.5	109.6	20.8	1.6	2.8	2	2	8	14
5	HPR-1506	**31.8**	95.5	94.3	18.1	8.2	0.0	0	0	0	0
6	HPR-1407	**31.4**	100.0	88.0	13.8	10.4	0.0	0	0	0	0
7	HPR-1384	**31.4**	96.5	96.5	17.2	8.0	0.0	0	0	0	0
8	HPR-312	**30.7**	96.5	101.8	16.1	7.5	0.0	0	0	0	0
9	HPR-691	**30.4**	93.0	105.0	12.8	7.2	0.0	0	0	0	0
10	HPR-119-1	**30.0**	97.5	84.0	30.4	6.4	0.6	5	1	50	60
Parents and checks											
1	BPT-5204 (P)	**30.6**	91.0	57.4	22.0	-10.0	10.0	9	9	900	1000
2	HP-14 (P)	**11.0**	102.0	94.8	13.0	11.3	0.0	0	0	0	0
3	MAS 946-1(C)	**12.4**	100.0	81.9	11.6	-3.3	7.0	5	2	8	18
4	MAS-26 (C)	**13.8**	98.5	81.4	11.7	-1.8	7.8	7	2	8	28
5	IR-64 (C)	**17.9**	95.5	62.3	12.6	-3.4	10.0	9	9	900	1000

P	:	Parents	C	:	Checks
GY	:	Grain yield/plant (g)	DFL	:	Days to flowering
PH	:	Plant height (cm),	PT	:	Productive tillers/plant
PE	:	Panicle exertion (cm)	ShLL	:	Sheath rot lesion length (cm)
ShR(SES)	:	Sheath rot incidence (SES) score	ShR(S)	:	Sheath rot severity score
DI	:	Disease indices			

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Table 5: Transgressive segregants for grain yield combined with sheath rot disease resistance and their parents under wetland condition in natural disease screening in rice during *kharif*-2013

Sl No	RIL's	GY	Grain yield related traits				Sheath rot related traits				
			DFL	PH	PT	PE	ShLL	ShR(SES)	ShR(S)	DI-1	DI-2
1	HPR-285	**32.9**	95.0	102.2	17.0	-2.7	0.0	0	0	0	0
2	HPR-2129	**31.3**	96.5	95.2	15.2	4.1	0.0	0	0	0	0
3	HPR-978	**30.6**	93.0	106.2	12.3	5.2	0.0	0	0	0	0
4	HPR-702	**30.4**	97.0	143.9	15.9	5.9	0.0	0	0	0	0
5	HPR-94-2	**29.6**	90.0	113.5	12.1	4.2	7.5	2	6	18	13
6	HPR-1514	**27.5**	98.0	71.7	14.3	-2.5	2.3	2	3	13	12
7	HPR-962	**27.4**	94.5	107.3	12.8	3.2	7.5	2	4	18	28
8	HPR-1505	**27.2**	85.0	105.2	16.2	2.8	2.5	2	1	3	13
9	HPR-1503	**27.1**	95.0	86.2	14.8	4.1	4.0	1	1	1	4
10	HPR-312-1	**26.5**	89.0	109.2	14.7	4.5	0.0	0	0	0	0
Parents and checks											
1	BPT-5204 (P)	**24.0**	97.0	75.5	11.2	-2.6	8.3	7	6	300	413
2	HP-14 (P)	**15.0**	90.5	109.1	7.5	5.2	0.0	0	0	0	0
3	MAS 946-1(C)	**12.7**	97.0	83.5	8.3	2.5	5.0	5	5	450	500
4	MAS-26 (C)	**14.6**	92.5	79.7	10.1	3.1	0.5	1	1	1	1
5	IR-64 (C)	**13.5**	76.5	56.5	17.9	-6.1	10.0	9	9	9	10

P	:	Parents	C	:	Checks
GY	:	Grain yield/plant (g)	DFL	:	Days to flowering
PH	:	Plant height (cm),	PT	:	Productive tillers/plant
PE	:	Panicle exertion (cm)	ShLL	:	Sheath rot lesion length (cm)
ShR(SES)	:	Sheath rot incidence (SES) score	ShR(S)	:	Sheath rot severity score
DI	:	Disease indices			