Developing and disseminating resilient and productive rice varieties for drought-prone environments in India: a network approach

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Introduction

Drought regularly affects 23 million ha of rainfed rice in South and Southeast Asia and is also widespread in rainfed environments in sub-Saharan Africa. The problem is particularly severe in Eastern India, with more than 10 million ha of drought-prone fields. Cultivars that combine drought tolerance with high yield potential under favorable conditions are therefore an important breeding objective. However, limited progress has been made so far, despite considerable research effort. Earlier, much of this effort has been devoted to secondary traits considered determinants of drought tolerance, rather than grain yield *per se* under drought stress. Recent research at IRRI has revealed that the selection for grain yield under stress can be carried out in a similar way as under nonstress conditions (Atlin et al. 2004) and that it is possible to develop cultivars combining improved drought tolerance with high yield potential under favorable moisture levels.

The Generation Challenge Program supports the IRRI−India Drought Breeding Network that links IRRI and eight Indian breeding programs serving drought-prone regions in a testing and germplasm exchange program with the objective of developing such cultivars. The network successfully evaluated 325 lines in the first year and 352 breeding lines, improved cultivars, and traditional varieties in the second year

for grain yield under a range of drought-stress conditions during the 2006 wet season. In addition, the Network evaluated in the Indian target environment the effect of a major QTL, *qtl12.1*, near SSR marker locus RM511 on chromosome 12, which was previously reported to explain 51 percent of the genetic variance for yield under severe upland stress in the Vandana/Way Rarem mapping population (Bernier et al. 2007).

Methods

During the second year experiments, breeding lines contributed by IRRI and member centers were evaluated under full irrigation (non-stress conditions) or in trials in which irrigation was withheld to generate moderate or severe stress. Trials of varieties maturing in <100 days were conducted under direct-sown upland conditions at Hazaribag and Faizabad, and separate trials of varieties maturing in 100–120 days or >120 days were conducted under transplanted management at Hazaribag, Faizabad Raipur and Coimbatore, and under upland management at Banglore. Nonstress control trials were also planted in each site. Stress was enhanced by draining paddies after transplanting, or, in upland trials, by planting on raised beds (Hazaribag). Planting was also delayed at Raipur to intensify stress. Grain yield, harvest index, plant height, and flowering date are the common variables collected at each site. Rainfall and mean water or water-table depth were used to characterize trial hydrology. For the evaluation of random Vandana/Way Rarem RILs with contrasting alleles for *qtl12.1,* ten random RILs with the drought-tolerance conferring allele at *qtl12.1* and ten without were evaluated under mild upland stress at Raipur and Birsa Agricultural University, Ranchi, and under severe managed stress in two trials (one in a rain-out shelter and one in raised beds) at Hazaribag.

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Results

- In the short−duration (<100 days) upland group, breeding lines **ASD17, CBO-13-1, RR345-2, CR143-2-2,** and **RR383-2** combined high yield potential under favorable conditions with good

yield under drought-stress conditions. These lines performed better than some of the widely grown upland lines (**Kalinga 3, Vandana, Anjali,** and **Ashoka**) in eastern India.

- In the medium−duration (100−120 days) group, the breeding lines **ARB2, ARB3, ARB4, ARB5, ARB6, ARB7, ARB8, IR74371-70-1-1, IR55419-04**, **CBO-15-24,** and **Tripuradhan** yielded more than 1.5 t ha^{-1} under severe drought stress and 3.7−4.5 t ha^{-1} under nonstress conditions. The widely grown varieties **IR64** and **IR36** in these regions yielded 0.9 and 0.7 t ha^{-1}, respectively under severe drought stress and 3.7 and 3.1 t ha^{-1}, respectively under non-stress conditions (Table 1).
- In the long−duration (120−140 days) group, the highly popular varieties **Swarna** and **Sambha Mahsuri** grown in these regions could not even set seed under severe drought stress. **Mahamaya**, a popular variety in the state of Chhattisgarh, yielded less than 0.1 t ha^{-1} and **Safri 17**, a moderately tolerant traditional Chhattisgarh cultivar, yielded only 0.3 t ha^{-1} under severe drought stress. At the same level of stress, the breeding line **Swarna/IR42253-54/116** was identified as promising, yielding an average of 2.4 t ha^{-1} (Table 2).
- IR74371-70-1-1, a breeding line identified by this network has been promoted to the second year of advanced yield testing (AYT) under the All India Crop Improvement Programme (AICRIP). ARB lines identified under this network have also been promoted for initial yield testing (IVT) under AICRIP in the same meeting.
- Unselected lines with the Way Rarem QTL allele at RM511 yielded at least three times more than random lines without QTL under severe stress at Hazaribag. There was no difference in yield under nonstress situations at Raipur and Ranchi (Fig. 1). These results confirm that *qtl12.1* has a strong effect on yield under severe stress in this cross, and that the effect is expressed under upland conditions at an Indian location.

References

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Acknowledgments

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Table 1. Promising lines of 100–120 days duration (AYT100-120): Line means over sites within stress levels (AM NOT SURE WHAT THIS SECOND LINE MEANS.)

Designation	Center	Variety type	Grain yield (tha^{-1})		
			Stress level		
			None	Moderate	Severe
ARB 2	UAS	Line	3.7	3.0	1.5
ARB 3	UAS	Line	4.5	2.9	1.6
ARB 4	UAS	Line	3.8	2.9	1.8
ARB 5	UAS	Line	4.0	2.9	1.6
CB0-15-24	TNAU	Line	3.9	2.7	1.9
IR 55419-04	IRRI	Line	3.8	2.4	1.5
IR 74371-70-1-1	IRRI	Line	3.8	1.9	1.5
RF 5329	IRRI	Line	3.7	2.5	1.7
Tripuradhan	CRURRS	Traditional	3.5	2.8	1.5
ARB 7	UAS	Line	3.8	2.9	2.1
ARB 8	UAS	Line	4.1	3.2	1.8
KRH 2 (hybrid)	Local	Variety	3.6	2.1	0.5
PA 6444 (hybrid)	Local	Variety	3.3	0.8	0
PA 6201 (hybrid)	Local	variety	3.6	1.3	0.3
PHB 71 (hybrid)	Local	variety	2.8	0.8	0.4
IR 64	IRRI	Variety	3.7	1.6	0.9
IR 36	IRRI	Variety	3.2	1.6	0.7
Mean			3.7	2.0	1.1
SED			0.5	0.4	0.4

Table 2. Advanced yield trial of greater than 120 days duration (AYTGT120): Line means at Raipur within stress levels

Designation	Center	Variety type	Grain yield (kg/ha)		
			Stress level		
			None	Moderate	Severe
Swarna/IR 42253-54/116	IGAU	Line	5.1	2.6	2.4
Swarna/IR42253-55-207	IGAU	Line	5.4	2.7	1.4
IR 70210-39-CPA-7-1-1-4-2	IRRI	Line	5.9	1.5	0.7
Safri 17	IGAU	Traditional	3.6	0.3	0.3
Mahamaya	IGAU	Variety	4.6	1.0	0.1
R 1216-6-1	IGAU	Line	4.1	0.1	0.2
Swarna	Check	Variety	3.1	0.0	0
Sambha Mahsuri	Check	Variety	2.9	0.1	0
PSBRC-9	IRRI	Variety	3.0	1.2	0
Mean			4.3	1.0	0.4
SED			1.0	0.3	0.2

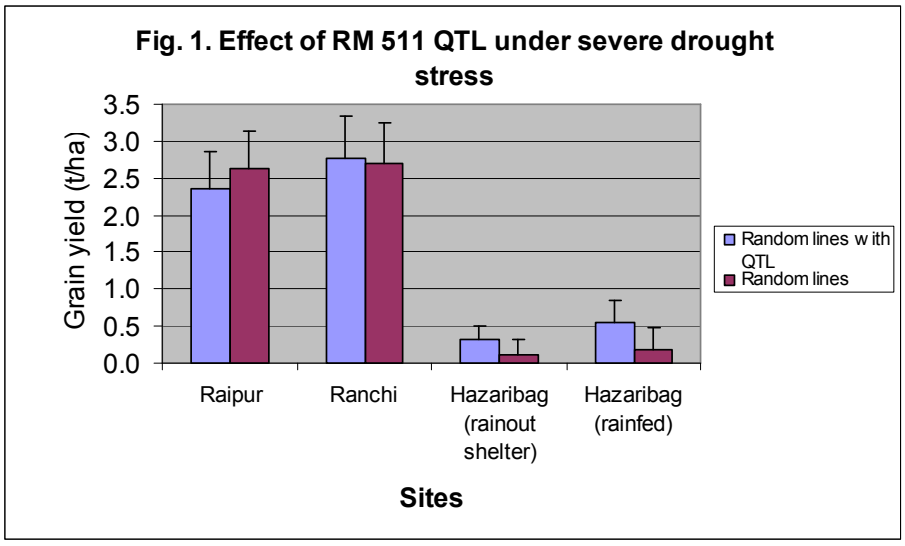

Fig. 2. On-farm trial, Higna Village, near Raipur, 2006: Severe lowland stress

Breeding line not selected for drought tolerance **Drought-tolerant line ARB 6**