Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP1: 185-190

Manish Kumar
Technical officer, Krishi Vigyan Kendra, Koderma, (ICAR-NRRI-CRURRS) Jharkhand, India

A Kumar
Assistant Professor, Dept. of Botany, Vinoba Bhave University, Hazaribag, Jharkhand, India

NP Mandal
Principle Scientist, Plant Breeding & Genetics, Central Rainfed Rice Research Station (ICAR-NRRI-CRURRS), Hazaribag, Jharkhand, India

Diwakar Prasad Nirala
SRF, Deptt. of Forest Products & Utilization, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Correspondence
Manish Kumar
Technical officer, Krishi Vigyan Kendra, Koderma, (ICAR-NRRI-CRURRS) Jharkhand, India

Evaluation of Aus germplasm population of rice under stress and non-stress conditions

Manish Kumar, A Kumar, NP Mandal and Diwakar Prasad Nirala

Abstract
Drought is the major abiotic factor that limit rice productivity in rainfed and upland ecosystems; worldwide, it reduce yield by 15–50% depend on the stress impact on crop growth period. Stress period more than 6-24 days occurs, drastic reduction observed in all the parameters i.e. average plant height 23.4-47.5%, panicle number 21.6-35.4%, yield of aus germplasm population 17.34-66.04% followed by an average of overall 41.69% over non-stress condition. Similarly it was found that biomass, harvest index, filled grain per panicle, total grain per panicle, fertility % and so on were reduced under stress condition in comparison to congenial condition.Variation in drought susceptibility index (DSI) and Drought resistant index (DRI) in the aus germplasm population ranges 1.081 to 2.116 and 0.24 to 3.80 respectively. Significant correlation and variations observed in the population for different agronomical traits & derived indices will facilitate selection aus germplasm population with drought tolerance and high yielding.

Keywords: Recombinant aus germplasm population (RILs), Drought Susceptibility Index (DSI), Drought Resistant Index (DRI), Stress, Non stress

Introduction
Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil. Rice (*Oryza sativa* L.) is a staple food for above 60% world's population. According to united nation estimate, the world population will grow from 6.3 million in 2003 to 8.0 million in 2025, requiring about 40% more rice production to cater the demand of the burgeoning global population. India is the foremost country of the world in area of rice cultivation and second to the China in rice production. The total area under rice cultivation in India is about 45 million hactre with a rice production of 87.00 million tones. It accounts for more than 40% of food grain production and providing employment to 70% people in rural area. India’s population currently stands at around 1100 million and increasing by growth rate of nearly 2% per year. The likely demand of rice, 143 Mt by 2030, has to be met by increased productivity as there is little scope to increase in the rice area cultivating in future.
Drought is a major abiotic stress that limits rice productivity in rainfed and upland ecosystems (Bimpong *et al*., 2011) and worldwide, drought affects approximately 27 million ha of rainfed (IRRI, 2011). Drought reduces yield by 15–50 per cent depending on the stress intensity and crop growth period at which the stress occurs in rice (Srividhya *et al*., 2011). Eastern India, comprising Jharkhand, Orissa, and Chhattisgarh alone accounts loss of about 40 per cent of the total rice production due to severe drought (Pandey and Bhandari, 2009). Developing high yielding and drought resistant varieties for rainfed area is priority for improving rainfed rice production.
Plant response to drought stress is one of the most complex biological processes, and it involves numerous changes at the physiological, cellular, and molecular levels. Many genes have been identified to be involved in the response of drought stress in plants (Zhang *et al*., 2012). The effect of drought on rice plants considerably varies with genotypes, developmental stages, and degree and duration of drought stress (Wang *et al*., 2011).
The narrow genetic base of modern crop cultivars is one of the serious obstacles to sustain and improve crop productivity due to rapid vulnerability of genetically uniform cultivars by potentially new biotic and abiotic stresses (Esbroeck *et al.,* 1999). Breeding for drought tolerance is complicated by the intermittent occurrence of natural stress, and by the strong relationship between plant phenology and sensitivity to stress (Fukai *et al.,* 1999). Donors for drought tolerance have been identified as CR143-2-2, Moroberekan, Salumpikit, N22, Kalakeri, Rasi, Brown gora etc. Traditional Aus type rice varieties are considered to be a valuable source of tolerance to moisture stress because of their adaptation to the fragile environment. Some progress has been made in breeding drought-tolerant varieties for

unbunded uplands (e.g. Vandana, Anjali, CR Dhan- 40 etc.) through conventional selection, but it is often slow due to poor control over selection environment.

Some rice cultivars particularly landraces contain a wealth of information that can explain the large morphological, physiological, and ecological variation. The innovative use of such diverse varieties will play a key role in reaching ambitious goal of high productivity in rice and also help to overcome future problems associated with narrowing genetic base of modern rice cultivars. The goal of research was to identify new sources of drought tolerance from locally adapted *aus* germplasm.

Materials and Methods

The experimental trials were conducted during 2012-2015 in the fields of Central Rainfed Upland Rice Research Station (CRURRS), Hazaribag and Krishi Vigyan Kendra, Jainagar, Koderma, Jharkhand, India (latitude 24^0 21\`53\`\`N,longitude $85^o$ 38\`58\`\`E, altitude 321 m of Jainagar, Koderma and latitude 23^0 59\`N, longitude $85^o$ 25\`E, altitude 610 m Hazaribag), located in north India.

Plant materials: In this study, a total of 96 population of aus germplasm of rice, representing different ecotypes and geographical origins were used. Seeds of the rice accessions were obtained CRURRS, Hazaribag, Jharkhand, India (Table-1).

Table 1: Details of 96 gora rice germplasm population used in the study

S. No	Designation	S. No.	Designation	S. No.	Designation
1	Br. Gora237	33	Black gora 89	65	china gora 268
2	Br. Gora 95	34	China gora 269	66	Dani gora 759
3	Br. Gora239	35	Black gora133	67	Brown gora109
4	BL.Gora226	36	Black gora 93	68	Brown gora231
5	Dani Gora 765	37	Birsa gora 102	69	Black gora101
6	Bangla Gora559	38	Black gora 117	70	China gora 279
7	Br. Gora762	39	Vandana	71	Brown gora 108
8	Br. Gora224	40	Dani gora 768	72	Brown gora85
9	BL.Gora 99	41	China gora279	73	Black gora116 A
10	Brown gora 710	42	Dular	74	Black gora111
11	Brown gora 229	43	Brown gora 219	75	Dani gora 334
12	Dani Gora 336	44	Brown gora 218	76	Black gora104
13	Brown gora 103	45	Brown gora 127	77	Black gora107
14	New dani 750	46	Brown gora225	78	Thara
15	China Gora 302	47	Brown gora 644	79	China gora276
16	Black Gora 128	48	Black gora 125	80	China gora280
17	karanga Gora 761	49	Black gora 120	81	Black gora115
18	China Gora 702	50	Black gora 129	82	T. gora 756
19	Black Gora 113	51	N-22	83	Brown gora 217
20	Black Gora 632	52	Lal Bhadoi	84	Black. Gora 105
21	Bangla Gora 598	53	Black gora 166	85	Black gora 131
22	Brown Gora 98	54	Brown gora 188	86	Brown gora 557
23	BlackGora 132	55	Brown gora 222	87	Black gora 221
24	Straw Gora 711	56	L 139 (7)	88	Black gora 121
25	Gora713	57	Brown gora 112	89	Black gora119
26	Brown Gora 116 B	58	Black gora 88	90	Brown gora232
27	Black gora 103	59	Brown gora 300	91	N.gora 752
28	kala dani 769	60	Brown gora 310	92	Black gora 87
29	Brown gora 220	61	Black gora 130	93	Kala gora 311
30	Kalakeri	62	kala gora766	94	China gora 703
31	Black gora 110	63	4) l-112	95	Black gora 124
32	Sathi 34-36	64	Gora white 712	96	Kalakeri

Field evaluation: The inbred populations of rice were evaluated under two different hydrological conditions viz., non stress (favorable or irrigated as per needed) & stress under rainfed condition during North-East monsoon, rainfed region in the experimental fields as above. Seeds of the rice lines were hand dibbled in dry soil before monsoon in 2.5 × 0.6 m^2 size plots with three replications under lattice square design and data collected were 50 per cent flowering, plant height, length of panicle, number of productive tillers/0.5m, number of grains/panicle, number of filled grains, grain yield kg per hactre, total biomass kg/ha.

Statistical analysis of the phenotypic data: Mean, range, standard deviation and correlation coefficient were worked out using Microsoft Excel statistical tools and SAS statistical package in order to check the genetic variance among the rice lines for all the traits.

Results and Discussion

Results obtained from the field experiments conducted with the objectives *viz*., to identify new sources of drought tolerance from locally adapted *aus* germplasm under stress and non stress condition for grain yield and drought tolerance.

1.1 Drought screening trial: A total of 96 population of rice, were sown and evaluated during kharif season from 2012-2015 (Table-1). The rainfall was also uneven during crop period with an intermittent drought spell spanning 14-25 days coinciding from flowering and grain filling stages. Aus germplasm showed variation in drought response under rainfed stress condition. Data on plant height, days to 50 per cent flowering, length of panicle, spikelet fertility, grain yield, straw yield and drought scores traits were recorded. The correlation coefficients are presented in table 1 and table 2 under non stress and stress condition respectively. Phenotypic variation indicated the presence of desired genes for the investigated traits among the rice accessions. These results are briefly described below.

1.2 Yield attributes: The means of, 50 per cent flowering (55.09 & 67.5), plant height (77.2 cm & 118.86 cm), length of panicle (21. 46 cm & 17.24 cm) number of productive tillers/0.5m (37.0 & 29.82), number of grains/panicle (91.41 & 51.94)), number of filled grains (97.59 & 65.45), grain yield q/ ha (18.9 & 6.40), total biomass q/ha (71.6 & 11.75) under stress condition and non stress condition respectively.
Under stress condition date of 50% flowering flowered 6-24 days after than the non stress condition. Drought stress delays flowering in crops (Fukai, 1999), which is due to low plant water status and longer delay in flowering is related to drought susceptibility (Kumar and Kujur, 2003). It is observed that average plant height reduced by 23.4-47.5%, panicle numbers drastically reduced to 21.6%-35.4%, yield of aus germplasm decreased from 17.34 -66.04% and average of 34.86%. Similarly it is observed that biomass, harvest index, filled grains, total grains, fertility etc phenotypic characters are less under stress condition in comparison to non stress condition. Plant-type traits such as plant height and tiller number modify the expression of secondary and integrative traits by affecting transpiration demand. Plant-type traits are highly heritable and are extensively used in traditional plant breeding (Cooper, 1999). Plant height is an important developmental and yield related trait (Zhao *et al.*, 2011).
The grain yield of rice was reduced by 5-38 per cent under mild water stress while severe water stress reduced grain yield by 25-67 per cent (Yang *et al.*, 1995). Babu *et al*., (2003) observed 67 per cent reduction in grain yield due to water stress. Jeong *et al*., (2010) showed that rice plants significantly enhanced drought tolerance at the reproductive stage, with a grain yield increase of 25 per cent to 42 per cent over the controls under field drought conditions.

1.3 Drought indicators: The ranges of drought attributes such as harvest index (0.01 - 1.18 and 0.097 - 1.20), under stress and non-stress condition with a mean of 0.361 and 0.47 in respectively. Spikelet fertility across the aus germplasm rice genotypes ranged from 0.0 to 91% under stress and 30.40 to 100.0% under non stress condition with a mean of 45.50 and 65.20%, respectively. Brown gora had higher spikelet fertility average (97.01%), while Dani gora 336, Black Gora 128, Brown Gora 229, Black Gora 99 and Black Gora 234 had lowest (0.00%) under stress conditions.
Genotypes having greater plant height are often larger in overall plant size, intercept more light and use water faster by transpiration, leading to lower plant water status (Kamoshita *et al.*, 2004), higher leaf death scores and more spikelet sterility (Pantuwan *et al.*, 2002a). Reduction in tiller production of tolerant rice varieties was reported to be marginal under drought situations as compared to susceptible varieties (Vijayalakshmi and Nagarajan, 1994).

1.4 Drought Score (leaf rolling score & leaf drying score): Mean drought score, leaf rolling score aus germplasm genotypes were 4.35 under stress condition and ranged from 0 to 8.70. Similarly the mean drought score, leaf drying score recorded across the aus germplasm genotypes were 1.31 under stress condition and ranged from 0 to 7.16.
Leaf rolling is one of the drought avoidance mechanisms to prevent water deficit during stress (O'Toole and Chang, 1979). Rolled leaves of rice transpire 41 per cent less water than did the unrolled ones (Courtois *et al*., 2002). Rice crop responds to drought condition by stomatal closure, leaf rolling, enhanced root growth, enhanced ABA production etc., to minimize water deficit (Price *et al*., 2002b). Leaf rolling and canopy temperature are also useful (Lafitte *et al.*, 2004; Hirayama *et al.*, 2006) for quickly screening of lines. The rate of yield or biomass reduction by stress (*e.g.* yield under stress as percent of yield under non-stress) is often used as an estimate of resistance in terms of plant production, in addition to absolute yield under stress. Spikelet fertility can be visually estimated under field conditions and has been used as an indirect index for drought screening in rice (Garrity and O'Toole, 1994; Fukai, 1999). The low value leaf drying score (LDS) i.e.0, 1, 2 etc. aus germplasm population are more resistant to stress environments and similar condition also observed for leaf rolling score.

1.5 Drought resistance index (DRI): It for aus germplasm rice varies from 0.24 to 3.80 with average of 2.02. The aus germplasm having higher value of DRI i.e Brown Gora95, Brown Gora 644, china Gora703, Black Gora105, Black Gora 632 etc. are comparatively more tolerance to drought than the low value DRI aus germplasm population i.e. others in table -1 etc. So that it make easier selection of aus germplasm.
Drought resistance index (DRI) for aus germplasm rice varies from 0.24 to 3.80 with average of 2.02. The aus germplasm having higher value of DRI i.e Brown Gora 95, Brown Gora 644, china Gora703, Black Gora105, Black Gora 632 etc. are comparatively more resistance/tolerance to drought than the low value DRI aus germplasm rice i.e. Dani gora 336, Black Gora 128, Brown Gora 229, Black Gora 99 and Black Gora 234 etc.

1.6 Drought susceptibility indexes (DSI): The variation of DSI for rice ranges from -1.081 to 2.116 and value of DSI made it possible to rank rice genotypes lines according to their drought tolerance in comparison to checks.
The values of DSI made it possible to rank the examined rice genotypes according to their drought tolerance. So that it make easier selection of desired lines/varieties. Leaf rolling is an important agronomic trait in rice breeding (Xiang *et al*., 2012). It is an adaptive response to water deficit, which helps in maintaining favorable water balance within plant tissues under conditions of water scarcity and depleting soil moisture (Singh and Singh, 1999). According to our earlier research (Grzesiak *et al*., 2012 drought susceptibility indexes (DSI) for maize and triticale genotypes were calculated by determining the changes in grain yield (GY) under two soil moisture levels (irrigated and drought).

1.7 Correlation coefficient analysis: Correlation coefficient between different yields attributes and drought indicators/index were significantly correlated with each other's given in table 2 & table 3 under stress and non stress condition respectively at 1% (0.149) & 5% (0.113) such as yield was significant with DTF at 5%(0.243) & at 1% with plant height(0.484) and panicle numbers (0.552). Similarly yield under non stress condition significantly correlated with at 1% with DTF (0.459), plant height (0.619) and panicle numbers (0.964). It is observed that biomass significantly correlated with DTF (0.394) & plant height (0.280) at 1% and panicle numbers (0.139) & yield (0.298) at 5% under stress so on for non stress (table 2 &3).

Table 2: Correlation Co-efficient among traits under stress conditions.

	DTF	APHT	P NO	GY	TBM	HI	FG	UFG	TG	FERT	STER	PL	LRS	LDS
DTF	1													
	1													
APHT	0.009^{NS}	1												
	0.881**	1												
P NO	-0.063^{NS}	-0.095^{NS}	1											
	0.346**	0.151**	1											
GY	-0.243*	0.046^{NS}	0.039^{NS}	1										
	0.0002^{NS}	0.484**	0.552**	1										
TBM	-0.056^{NS}	0.071^{NS}	0.139	0.298	1									
	0.394**	0.280**	0.035^{NS}	0.0001^{NS}	1									
HI	-0.231	-0.015^{NS}	-0.046^{NS}	0.684*	-0.215	1								
	0.001^{NS}	0.817**	0.483**	0.0001^{NS}	0.001^{NS}	1								
FG	0.019^{NS}	0.098^{NS}	0.038^{NS}	0.001^{NS}	0.040^{NS}	-0.040^{NS}	1							
	0.774**	0.139**	0.561**	0.987**	0.542**	0.545**	1							
UFG	0.046^{NS}	-0.043^{NS}	-0.045^{NS}	0.025^{NS}	0.023^{NS}	0.026^{NS}	-0.458*	1						
	0.487**	0.512**	0.497**	0.698**	0.719**	0.689**	0.0001	1						
TG	-0.031^{NS}	0.041^{NS}	-0.013^{NS}	0.0285^{NS}	0.063^{NS}	-0.009^{NS}	0.396*	0.633	1					
	0.644**	0.537**	0.845**	0.667**	0.341**	0.890**	0.0001^{NS}	0.0001^{NS}	1					
PF	0.013^{NS}	0.077^{NS}	0.067^{NS}	-0.035^{NS}	-0.002^{NS}	-0.048^{NS}	0.781*	-0.869	-0.218	1				
	0.844**	0.243**	0.312**	0.590**	0.976**	0.467**	0.0001^{NS}	0.0001^{NS}	0.0009^{NS}	1				
PS	-0.013^{NS}	-0.077^{NS}	-0.067^{NS}	0.035^{NS}	0.002^{NS}	0.048^{NS}	-0.781	0.869	0.218	-1	1			
	0.844**	0.243**	0.312**	0.590**	0.976**	0.467**	0.0001^{NS}	0.0001^{NS}	0.0009^{NS}	0.0001^{NS}	1			
PL	0.092^{NS}	-0.068^{NS}	0.059^{NS}	-0.072^{NS}	-0.012^{NS}	-0.002^{NS}	0.055^{NS}	-0.102^{NS}	-0.056^{NS}	0.099^{NS}	-0.998	1		
	0.163**	0.306**	0.367**	0.276**	0.8539**	0.974**	0.402**	0.129	0.397**	0.139	0.132	1		
LRS	0.095^{NS}	-0.055^{NS}	0.066^{NS}	-0.078^{NS}	0.002^{NS}	-0.085^{NS}	0.023^{NS}	-0.068^{NS}	-0.068^{NS}	0.060^{NS}	-0.603	0.918	1	
	0.151**	0.404**	0.319 **	0.2374**	0.982**	0.199**	0.732**	0.3061	0.3606	0.3644	0.3644	0.001^{NS}	1	
LDS	-0.069^{NS}	-0.018^{NS}	0.004^{NS}	-0.038^{NS}	0.101^{NS}	-0.085^{NS}	0.059^{NS}	-0.047^{NS}	0.0064^{NS}	-0.060^{NS}	0.199	0.199	0.224	1
	0.30 **	0.787 **	0.955 **	0.566**	0.127**	0.197**	0.368 **	0.922**	0.479**	0.361**	0.002^{NS}	0.002^{NS}	0.0007^{NS}	1

Significance at 1% level** (0.149) and at 5% level* (0.113), NS-non significant

DTF- Days to 50% flowering,, APHT-Average Plant Height (cm), P No-panicle no. in 0.5m, GY Grain yield in Kg/ha, TBM- Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grains per panicle, PF.- fertility, PS.- sterility and PL- Panicle length (cm), FERT-Fertility, STER-Sterilty, LRS-Leaf rolling score & LDS-Leaf drying score.

Table 3: Correlation Co-efficient among traits under non-stress conditions

	DTF	APHT	P NO	GY	TBM	HI	FG	UFG	TG	FERT	STER	PL
DTF	1*											
	1											
APHT	0.094^{NS}	1										
	0.154**	1										
P NO	-0.133*	0.039^{NS}	1									
	0.044^{NS}	0.555**	1									
GY	-0.049^{NS}	0.033^{NS}	-0.003^{NS}	1								
	0.459**	0.619**	0.964**	1								
TBM	0.044^{NS}	0.097^{NS}	0.039^{NS}	0.407*	1							
	0.507^{NS}	0.140**	0.549**	0.0001^{NS}	1							
HI	-0.101^{NS}	-0.117*	-0.711*	0.622*	-0.250*	1						
	0.127^{NS}	0.0763^{NS}	0.280**	0.0001^{NS}	0.0001^{NS}	1						
FG	-0.076^{NS}	0.049^{NS}	-0.110^{NS}	0.024^{NS}	0.037^{NS}	0.047^{NS}	1					
	0.248**	0.458**	0.0968^{NS}	0.710**	0.575**	0.478**	1					
UFG	-0.053^{NS}	-0.006^{NS}	0.036^{NS}	-0.041^{NS}	-0.059^{NS}	-0.044^{NS}	-0.054^{NS}	1				
	0.425**	0.927**	0.586**	0.531**	0.373**	0.505**	0.415**	1				
TG	-0.094^{NS}	0.042^{NS}	-0.085^{NS}	0.004^{NS}	0.008^{NS}	0.021^{NS}	0.890	0.405	1			
	0.157**	0.525**	0.196**	0.943**	0.901**	0.741**	0.0001^{NS}	0.0001^{NS}	1			
PF	0.020^{NS}	0.034^{NS}	-0.078^{NS}	0.052^{NS}	0.067^{NS}	0.061^{NS}	0.519*	-0.845*	0.091^{NS}	1		
	0.762**	0.602**	0.239**	0.428**	0.307**	0.355**	0.0001	0.0001	0.17**	1		
PS	0.020^{NS}	-0.034^{NS}	0.078^{NS}	-0.052^{NS}	-0.067^{NS}	-0.061^{NS}	-0.519*	0.845 *	-0.091^{NS}	-1	1	
	0.762**	0.602**	0.239**	0.428**	0.307**	0.355**	0.0001^{NS}	0.0001^{NS}	0.169**	0.0001^{NS}	1	
PL	0.152*	0.085^{NS}	-0.021^{NS}	0.038^{NS}	0.003^{NS}	-0.003^{NS}	0.073^{NS}	-0.027^{NS}	-0.080^{NS}	0.006	-0.006^{NS}	1
	0.022^{NS}	0.199**	0.759**	0.561**	0.964**	0.960**	0.266**	0.682**	0.228**	0.925**	0.925**	1

Significance at 1% level** (0.149) and at 5% level* (0.113), NS-non significant

DTF- Days to 50% flowering,, APHT-Average Plant Height (cm),, P No-panicle no. in 0.5m, yield in Kg/ha, TBM- Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grains per panicle, PF.- fertility, PS.- sterility and PL- Panicle length (cm FERT-Fertility, STER-Sterility.

Grain yield under drought has been reported to be a function of biomass production and harvest index at the vegetative and reproductive stage respectively (Atlin *et al*., 2008). Grain yield under drought stress is a complex quantitative trait whose repeatability is thought to be low relative to yield in non-stress environments, reducing selection efficiency (Fukai and Cooper, 1995; Venuprasad *et al*., 2007). Panicle length was positively correlated with number of grains per panicle, straw yield total biomass and root thickness under rainfed condition. Mirza *et al*., (1992) found panicle length was positively correlated with number of grains per panicle. Harvest index was positively correlated with grain number, percentage spikelet fertility and yield in rice. In the current study, the traits such as days to heading, number of chaffs and panicle length had negative correlations with harvest index. Li *et al*., (2012) also reported harvest index was negatively correlated with days to fifty percent flowering, panicle length. Spikelet fertility is the most important yield component trait under water stress condition (Cruz and O' Toole, 1984).

Conclusion

Rice, (*Oryza sativa* L.) is one of the most important crops providing staple food for a large segment of the world population. Drought stress is a major limitation to rice yields and its stability in rainfed areas. Developing drought resistant cultivars will help to increase production of rice in rainfed area. Developing high yielding and drought resistant varieties for rainfed area is priority for improving rainfed rice production.

Plant response to drought stress is one of the most complex biological processes some rice cultivars particularly landraces contain a wealth of information that can explain the large morphological, physiological, and ecological variation. The innovative use of such diverse varieties will play a key role in reaching ambitious goal of high productivity in rice and also help to overcome future problems associated with narrowing genetic base of modern rice cultivars. It has now been demonstrated that drought–tolerant upland rice can be bred by directly selecting for yield in stress environments. By the evaluation of aus germplasm population under stress and non stress condition for grain yield and drought resistance we can be developed new spectrum for germplasm which tolerant to stress as well as more yielding.

References

1. Atlin G, Venuprasad R, Bernier J, Zhao D, Virk P, Kumar A. Rice germplasm development for drought-prone environments: Progress made in breeding and genetic analysis at the IRRI. Drought frontiers in rice: Crop improvement for increased rainfed production. World Scientific Publishing, Singapore, Singapore, and IRRI, Los Baños, Philippines, 2008, 35-59.
2. Babu RC, Nguyen BD, Chamarerk V, Shanmugasundaram P, Chezhian P, Jeyaprakash P *et al*. Genetic analysis of drought resistance in rice by molecular markers: Association between secondary traits and field performance. *Crop Science,* 2003; 43:1457-1469.
3. Bidinger FR, Mahalakshmi Y, Talukdar BS Alagarswamy G. Improvement of drought resistance in pearl millet. In IRRI (Ed) Drought Resistance in Crops with Emphasis on Rice. IRRI, Los Banos, Laguna Philippines, 1982, 357-375.
4. Bimpong IKR, Serraj JH, Chin J, Ramos EMT, Mendoza JE, Hernandez MS *et al*. Identification of QTLs for Drought-Related Traits in Alien Introgression Lines Derived from Crosses of Rice (Oryza sativa cv. IR64) × O. glaberrima under Lowland Moisture Stress. J. of Plant Bio, 2011; 54:237-250.
5. Cooper M. Concepts and strategies for plant adaptation research in rainfed lowland rice. Field Crop Res 1999; 64:13-34.
6. Courtois B, Lafitte HR. Interpreting cultivar environment interactions for yield in upland rice assigning value to drought-adaptive traits. Crop Sci, 2002; 42:1409–1420.
7. Cruz RT, O'Toole JC. Dryland rice response to an irrigation gradient at flowering stage. Agron Journal, 1984; 76:178-183.
8. Esbroeck VGA, Bowman DT, May OL, Calhoun DS. Genetic similarity indices for ancestral cotton cultivars and their impact on genetic diversity estimates of modern cultivars. Crop Science, 1999; 39:323-328.
9. FAO (Food and Agriculture Organization) Rome. 2011. http://faostat.fao.org.
10. Fischer RA, Maurer R. Drought resistance in spring wheat cultivars. I. Grain yield response. Aust. J. Agric. Res, 1978; 29:897-907.
11. Fukai S, Cooper M. Development of drought resistant cultivars using physiomorphological traits in rice. Field Crop Res, 1995; 40:67-86.
12. Fukai S. Phenology in rainfed lowland rice. Field Crop Res 1999; 64(1-2):51-60.
13. Garrity D, O'Toole J. Screening rice for drought resistance at the reproductive phase. Field Crops Res, 1994; 39:99-110.
14. Grzesiak MT, Marcin´ska I, Janowiak F, Rzepka A, Hura T. The relationship between seedling growth and grain yield under drought conditions in maize and triticale genotypes. *Acta Physiol Plantarum*, 2012. doi:10.1007/s11738-012-0973-3.
15. Hirayama M, Wada Y, Nemoto H. Estimation of drought tolerance based on leaf temperature in upland rice breeding. Breed Sci, 2006; 56:47–54.
16. IRRI (International rice research institute). 2011.
17. Jeong JS, Kim YS, Baek KH, Jung H, Ha SH, Do Choi *et al.* Root-specific expression of OsNAC10 improves drought tolerance and grain yield in rice under field drought conditions. Plant Physiol, 2010; 153:185-97.
18. Kamoshita A, Rodriguez R, Yamauchi A, Wade LJ. Genotypic variation in response of rainfed-lowland rice to prolonged drought and rewatering. Plant Prod Sci, 2004; **7**:406-420.
19. Kumar R, Kujur R. Role of secondary traits in improving the drought tolerance during flowering stage in rice**.** *Indian J of Plant Physio,* 2003; 8:236-240.
20. Lafitte HR, Price AH, Courtois B. Yield response to water deficit in an upland rice mapping population: Associations among traits and genetic markers. *Theor. Appl. Genet,* 2004; 109:1237-1246.
21. Li X, Yan W, Agrama H, Jia L, Jackson A, Moldenhauer K *et al*. Unraveling the complex trait of harvest index with association mapping in rice (*Oryza sativa* L.), *PLoS ONE.***7**: e29350. 2012.
22. Mirza MJ, Faiz FA, Majid A. Correlation studies and path analysis of plant height, yield and yield components in rice (*Oryza sativa* L.). Sarhad J Agril. 1992; 8(6):647-653.
23. O'toole J, Chang T. Drought resistance in cereals. Rice: A case study. Stress physiol. in crop plants, 1979; 64:628.
24. Pandey S, Bhandari H. Drought: coping mechanism and

poverty, Insights from rainfed rice farming in Asia and the pacific division. International Fund for Agricultural Development (IFAD), 2009, 5-43.

25. Pantuwan G, Fukai S, Cooper M, Rajatasereekul S, O'Toole JC. Yield response of rice (*Oryza sativa* L.) genotypes to different types of drought under rainfed lowlands. 2. Selection of drought resistant genotypes. Field Crop Research, 2002a; 73:169-180.
26. Price AH, Cairns JE, Horton P, Jones HG, Griffiths H. Linking drought-resistance in upland rice using a QTL approach: progress and new opportunities to integrate stomatal and mesophyll responses. Journal Expt Botany, 2002b; 53:989-1004.
27. Sellamuthu R, Liu GF, Ranganathan CB, Serraj R. Genetic analysis and validation of quantitative trait loci associated with reproductive-growth traits and grain yield under drought stress in a doubled haploid line population of rice (*Oryza sativa* L.). Field Crops Research, 2011; 124:46-58.
28. Singh S, Singh TN. Morphological, chemical and environmental factors affecting leaf rolling in rice during water stress. Indian J. Plant Physiology, 1999; 5:136-141.
29. Srividhya A, Vemireddy LR, Sridhar S, Jayaprada M, Ramanarao PV, Hariprasad AS *et al*. Molecular Mapping of QTLs for Yield and its Components under Two Water Supply Conditions in Rice (Oryza sativa L.). J. Crop Sci. Biotechnology, 2011; 14(1):45-56.
30. Venuprasad R, Lafitte HR, Atlin GN. Response to Direct Selection for Grain Yield under Drought Stress in Rice. Crop Science, 2007; 47:285.
31. Vijayalakshmi C, Nagarajan M. Effect of rooting pattern on rice productivity under different water regimes. J. Agronomy and Crop Science, 1994; 173:113-117.
32. Wang WS, Pan YJ, Zhao XQ, Dwivedi D, Zhu LH, Ali J *et al*. Drought-induced site-specific DNA methylation and its association with drought tolerance in rice (*Oryza sativa* L.). J Exp Bot. 2011; 62:1951-60.
33. Xiang JJ, Zhang GH, Qian Q, Xue HW. Semi-Rolled Leaf1 Encodes a Putative Glycosylphosphatidylinositol-Anchored Protein and Modulates Rice Leaf Rolling by Regulating the Formation of Bulliform Cells. Plant Physiol. 2012; 159:1488-500.
34. Yang S, Logan J, Coffey DL. Mathematical formulae for calculating the base temperature for growing degree days. Agric. Water Management, 1995; 74:61–74.
35. Zhang LS, Yu K, Zuo Luo L, Tang K. Identification of Gene Modules Associated with Drought Response in Rice by Network-Based Analysis. PLoS ONE, 2012; 7:e33748.
36. Zhao K, Eizenga CW, Wright GC, Ali MH, Price ML, Norton AH *et al*. Genome-wide association mapping reveals a rich genetic architecture of complex traits in *Oryza sativa*. Nat. Communication, 2011; 2:467.