Electronic Journal of Plant Breeding, 2(3):295- 302 (Sep 2011)
ISSN 0975-928X

Research Article

Effect of drought on yield potential and drought susceptibility index of promising aerobic rice (*Oryza sativa* L.) genotypes

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(Received:16 Jun 2011; Accepted:20 Jul 2011)

Abstract:
Selection of drought tolerance is highly complex and involves evaluating genotypes either for high yield potential or stable performance under varying degrees of water stress. Seventeen advanced rice genotypes were evaluated under aerobic and water stress condition at Department of Genetic and Plant Breeding, GKVK, UAS, Bangalore during *summer* 2010. Water stress was imposed at late vegetative stage by withholding irrigation supply in one experiment for 15 days and other was maintained as aerobic control. Drought susceptibility index (DSI) and Relative yield (RY) values were used to describe yield stability and relative yield among genotypes. In the present study, there were high variations in drought susceptibility index and relative yield among genotypes. DSI values ranged from -9.37 (25P25) to 18.48 (IR 68897B) and mean RY values were 0.707 and 0.752 for Aerobic condition and water stress respectively. Higher relative yield under water stress indicated the positive response of genotypes to drought. The varieties MAS26, SEL 128, 25P25, PHB 71, MAS25, IR 58025B and MAS946-1 showed high yield potential and yield stability (i. e., DSI < 1 and RY > mean RY). MAS26 and SEL 128 not only have yield stability but they also have high per day productivity per drop of water. So these varieties could be further tested for drought confirming characters and could be used as donor parents in drought tolerance breeding in rice.

Key words: Aerobic Rice, DSI, Dry Hydrology, Relative Yield, Water stress

Introduction

Rice is the staple food crop for more than two thirds of the world population and gives 35-60% of calories requirement (Khush, 1996). Food security of the India directly related to rice production. Water reservoirs are decreasing due to intermittent drought and erratic rainfall which compelled the rice growers across Asia to switch over crops. The increasing scarcity of water threatens the irrigated rice production system in one hand and increased pressure on food production due to increasing population. To combate this situation it is essential that alternate ways of rice cultivation with less water and without compromising on yield were evolved and popularized. Aerobic rice cultivation with suitable drought tolerant varieties addressed earlier in suboptimal situation (Hittalmani and Shivashankar, 1987) were benefiting answer to address the water scarce situation already set in and for near future. However with the global warming symptoms rapidly spreading, growing rice in less water with suitable adapted varieties/hybrids under intermittent drought is the requirement of the day to keep rice production sustainable. Efforts were made to develop varieties suited to aerobic condition and few varieties are now available for aerobic cultivation (MAS 946-1, MAS 26 and MAS 868 in India developed by UAS Bangalore). However there is need to identify the response of these varieties to drought at different growth stages and could be used for further breeding programmes like heterosis breeding.

Drought is the most important abiotic constraint that reduces yield in rainfed areas and contributing to 15 per cent loss in rice production annually in India (Dey and Upadhaya, 1996). The average yield in rainfed areas is low because of periodic drought and adverse soil and lack of improved varieties (Mall *et al*. 2011). Drought resistance appears to be the single most important factor in increasing and stabilizing rice production under rainfed areas (O'Toole, 1982). Genetic studies show that adaptive mechanisms to drought in rice are heritable and controlled by complex quantitative characters (Chaudhary and Rao, 1982; Kumar *et al*., 2008).

The most widely used criteria for selecting high yield performance are mean yield, mean productivity and relative yield performance in drought stressed and favorable environment. Ahemad *et al*., (1999) found relative grain yield to be a useful criteria for assessing drought response of genotype and Fisher and Maurer (1978) proposed the use of drought susceptibility index (DSI), which characterized the yield stability between two environments. The combination of high yield stability and high relative yield under drought has been proposed as useful selection criteria for characterizing genotypic performance under varying degrees of water stress (Ahmad *et al*., 2003). The objective of this investigation is to study yield potential and stability of selected Aerobic/drought tolerant genotypes under stress situation and to select lines for further breeding programme.

Material and Methods

Fifteen selected advanced/released Rice genotypes and two private rice hybrids were screened to identify drought tolerant stable high yielders. The brief description of the material used in the study is provided in Table 1. The experiment was carried out at Department of Genetics and Plant Breeding, GKVK, University of Agricultural Sciences, Bangalore during summer 2010. The experiment was laid out in Randomized Block Design (RBD) with two replications each under aerobic condition (E1) and water stress condition (E2). The direct sowing was done in both E1 and E2 with spacing of 25 × 20cm and each genotype was maintained in two rows of length 2 meter. To overcome boarder effect observations were made on middle plants in the row. Both the experiments were maintained by following standard package of practices of Aerobic rice cultivation (UAS, Aerobic Rice Broachers 2007) up to 55 days after sowing (DAS). Irrigation was withdrawn after 55 DAS to 75 DAS in water stress experiment (E2) and other experiment (E1) as control by following normal aerobic cultivation with irrigation once in 5-6 day. Stressed plot was re-watered for recovery after drought induction. Soil moisture content (SMC) during stress period was monitored through periodical soil sampling at 0–15cm, 15–30cm, 30–45cm, 45–60cm soil depth. Drought score and recovery observations were recorded following SES, on a 1 to 9 scale (IRRI, 1996). The observations were recorded in both experiments on five competitive plants at centre of the row for yield and yield attribute characters. The measure of yield stability (DSI) and relative yield potential were calculated from mean yield. DSI (Fischer and Maurer, 1978) was as

$DSI = (1-Yd/Yw)/D$

Where Yd = mean yield under drought, Yw = mean yield under transplanted/aerobic conditions, and D = environmental stress intensity = 1-(mean yield of all genotypes under drought/mean yield of all genotypes under Aerobic/transplanted conditions). The relative yield under drought was calculated as the yield of a specific genotype under drought divided by that of the highest yielding genotype in the population.

Results and Discussion

Drought susceptibility index: On the basis of experimental mean, yield was slightly affected under late vegetative stress condition compare to normal aerobic condition. Differences for DSI among genotypes were analyzed for yield (Table 2) and yield attributes traits (data not given). In general more than 50 per cent of genotypes in the study expressed low DSI values (< 1) for yield. The DSI values for yield varied from -9.37 (25P25) to 18.38 (IR 68897B). Some genotypes expressed negative DSI values which indicated their superior performance under stress compare to Aerobic condition. The promising genotypes in ascending order with low DSI values for yield are 25P25 (-9.37), qRT(1+7)-5 (-7.79), IR58025B (-7.44), PHB71 (-7.11), MAS26 (-7.10) and SEL 128 (-2.25). The top five drought tolerant genotypes with stable yield with more than 7 t ha^{-1} under stress are MAS26, SEL 128, 25P25, PHB71 and MAS25 as indicated by their low DSI values for yield.

Drought susceptibility index is measure as yield stability. The lower mean values of DSI (< 1) of a genotype for yield indicated the relative tolerance of its characters to drought stress. However higher DSI (> 1) values of genotypes showed that these genotypes are relatively prone to drought stress. The promising genotypes MAS26, SEL 128, 25P25, PHB 71 and MAS25 with low DSI recorded more than 7 t ha^{-1} under stress condition. The results indicated that the above said genotypes produced higher yield (>1 t ha^{-1}) under drought stress compared to aerobic condition attributed to their specific adaptation and other drought tolerant traits such as root traits (Chauhan *et al.,* 2007). The presence of large variation in the DSI values for certain genotypes might be due to timing, intensity and stage of stress and genetic diversity among lines (Clarke *et al.,* 1984). In the present study moisture stress at late vegetative stage has no harmful effect and instead it triggers the drought responsive yield QTLs thereby some genotypes recorded high yield under stress. The late vegetative stress is not more harmful than that at early vegetative stress due to adult plant tolerance (Adhikari *et al.,* 1999). The rice genotypes with drought tolerant traits are known to produce high seed yield under drought condition (Naresh Babu *et al.*, 2010; Mall *et al.* ,2011). MAS 26 and SEL 128 are considered as best among the top genotypes with low DSI and high grain yield. There is need to evaluate identified lines under varying degrees of stress at different growth stages for different drought tolerant traits

Relative yield under Drought and Aerobic condition: The mean relative grain yield values under water stress and aerobic condition were 0.752 and 0.707 respectively (Table 2). Mean relative yield in case water stress marginally more than that of aerobic control. Genotypes MAS26, SEL 128, 25P25, PHB71, MAS946-1 and IR58025B were relatively high yielding under water stress (RY > mean RY), while IR68897B, MAS109, MAS868, IR68888B and Nellor sona were relatively low yielder (RY < mean RY). The genotypes IET21574 (8.52 t ha^{-1}), IR79156B (7.4 t ha^{-1}), MAS946-1 (7.28 t ha^{-1}), 0YR128 (6.9 t ha^{-1}) and MAS26 (6.8 t ha^{-1}) were relatively high yielding under aerobic condition (RY > mean RY). The remaining genotypes recorded lower relative yields under aerobic condition.

Relative yield could be used to assess the yield potential of a genotype under water stress condition. Higher relative yield shows that genotypes performed relatively well under drought. The higher mean RY under drought indicated the adaptive nature of genotypes to moisture stress. The varieties MAS26, SEL 128, and 25P25 which exhibited higher RY under stress show their adaptive nature. It is a relative mean value where single inferior genotype might affect the overall mean and therefore it requires confirmation by evaluating under varying moisture stress situation. IET 21574, MAS 946-1 and IR79156B showed higher RY under aerobic condition and indicated their susceptibility to drought. The results revealed that there is need to breed for genotypes for each special growing condition of rice, which is really challenging task to the breeder.

Drought tolerant genotype is one which has short duration with high yield but genotypes exposed to drought causes increased duration and reduced yield. In the present study, range of 6 days (MAS 868) to 2 days (IET 21594) increased days to maturity was observed under drought compare to aerobic condition. This increase of duration indicates their tolerance to drought. Spikelet and pollen fertility of all genotypes under both conditions are presented in Table 3. There is no significant changes in spikelet and pollen fertility under both conditions but slight decrease of spikelet fertility under drought conditions causes significant yield loss in genotypes MAS 946-1, IR 68897B and MAS 868. MAS 26, SEL 128, 25P25 and PHB 71 showed higher yield under drought because these varieties were specifically bred for drought and also better expression of root QTLs but in hybrids may be due to innate buffering to drought. Per day productivity per ha (Table 3) ranged from 66.56 kg (IET 21594) to 33.28 kg (IR 68897B) under Aerobic and 56.436 kg (MAS 26) to 13.94kg (IR 68897B) under drought condition. Per day productivity is important trait which gives the relation between maturity duration and yield. There is need to conduct water controlled experiments using new phenomic techniques,there by we can estimate precise Drought value of genotypes

Rice breeding in India is making continuous efforts to break the ceiling of yield and exhibit vigor for higher production with limited water available. There is also need to develop rice varieties/ hybrids that will produce stable yields in both water limited and favorable environments. In this view MAS26, MAS25, SEL 128, MAS946-1, IR58025B and qRT(1+7)-5 are considered as promising genotypes based on lower DSI values of yield and RY under stress and could be used as donors in hybridization programme. Besides IR 58025B and IR 68888B are drought tolerant maintainers and could be used for hybrid breeding for drought condition. Present study also revealed that hybrids (25P25 and PHB 71) have a high drought tolerant nature compared to most of inbred varieties due to high vigor combined with heterotic buffering capacity. There is need to evaluate all identified promising genotypes with varying moisture stress at different growth stages for different drought related characters. Identified drought tolerant maintainer lines and advanced aerobic lines could be used in test cross nursery to develop drought tolerance rice hybrids.

Acknowledgments

We are thankful to Pioneer Hi-Bred International, Inc.(Pioneer), Jhonston who provided Scholarship to the senior authors Masters research for their kind support throughout my research. Special Thanks to DRR Hyderabad for providing CMS and maintainer lines for my research.

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Table 1: Details of Rice genotypes

Genotype	Habit	Duration	Place of collection	Special Features
MAS26	Semi dwarf	125	MAS Lab GKVK	High yielding Aerobic Variety released through MAS, medium to fine grains
MAS25	Semi dwarf	125	MAS Lab GKVK	Advanced Aerobic Line
MAS946-1	Semi dwarf	120	MAS Lab GKVK	High yielding Aerobic Variety released through MAS, Medium Grains
MAS109	Semi dwarf	115	MAS Lab GKVK	Short duration Advanced Aerobic line
MAS868	dwarf	135	MAS Lab GKVK	High yielding Aerobic variety (Pipe Line)
qRT(1+7)-5	Semi dwarf	130	MAS Lab GKVK	High yielding Root QTL Pyramid line (1+7 combination)
qRT (1+7)-8	Semi dwarf	135	MAS Lab GKVK	High yielding Root QTL Pyramid line (1+7 combination)
OYT 58	Semi dwarf	128	IRRI	High yielding selection under Aerobic condition from IRRI lines
SEL 128	Semi dwarf	130	IRRI	High yielding selections under Aerobic condition from IRRI lines
NELLORE SONA	Semi dwarf	130	MAS Lab GKVK	Upland rice variety well adopted in Aerobic condition
IET21594	Semi dwarf	125	MAS Lab GKVK	High yielding selection under Aerobic condition
IR68888 B	Semi dwarf	125	DRR Hyderabad	Medium duration Maintainer released for irrigated condition
IR68897 B	Semi dwarf	120	DRR Hyderabad	Medium (early) duration Maintainer released for irrigated condition
IR58025 B	Semi dwarf	135	DRR Hyderabad	Medium duration Maintainer released for irrigated condition
IR79156 B	Semi dwarf	135	DRR Hyderabad	Medium duration Maintainer released for irrigated condition
25P25	Semi dwarf	125	Pioneer Hybrid	High yielding Private hybrid released for irrigated condition
PHB 71	Semi dwarf	130	Pioneer Hybrid	High yielding Private hybrid released for irrigated condition

Table 2: Effect of Moisture stress on Drought Susceptibility Index(DSI) and Relative yield (RY) in Selected Rice Genotypes

Genotype	Yield (t ha^{-1}) Aerobic	yield (t^{-1} ha^{-1}) water stress	DSI	RY Aerobic condition	RY water stress
MAS 26	6.360	7.760	-7.10	0.746	1.000
MAS 25	6.800	6.880	-0.38	0.798	0.887
MAS 946-1	7.280	6.220	4.70	0.854	0.802
MAS 109	3.980	3.960	0.16	0.467	0.510
MAS 868	6.360	4.600	8.93	0.746	0.593
qRT(1+7)-5	4.640	5.760	-7.79	0.545	0.742
QRT (1+7)-8	5.360	5.640	-1.69	0.629	0.727
OYT 58	6.420	5.860	2.81	0.754	0.755
SEL 128	6.880	7.360	-2.25	0.808	0.948
Nellore Sona	6.780	5.320	6.95	0.796	0.686
IET 21594	8.520	6.200	8.78	1.000	0.799
IR 68888 B	4.620	5.120	-3.49	0.542	0.660
IR 68897 B	4.260	1.820	18.48	0.500	0.235
IR 58025 B	5.200	6.400	-7.44	0.610	0.825
IR 79156 B	7.400	5.900	6.54	0.869	0.760
25P25	5.580	7.200	-9.37	0.655	0.928
PHB 71	5.900	7.200	-7.11	0.692	0.928
Mean	6.020	5.835		0.707	0.752

Table 3. Pollen fertility, spikelet fertility and per day productivity of selected rice genotypes under aerobic and drought situations

	Pollen fertility %		Spikelet Fertility%		Days to maturity		Yield (t/ha)		Per day productivity(kg/ha)	
Genotypes	**Aerobic**	**Drought**	**Aerobic**	**Drought**	**Aerobic**	**Drought**	**Aerobic**	**Drought**	**Aerobic**	**Drought**
MAS 26	99.3	99.3	87.21122	85.36122	135.5	137.5	6.36	7.76	46.937	56.436
MAS 25	98.1	98.1	93.70876	91.85876	134.5	138	6.8	6.88	50.558	49.855
MAS 946-1	100	96.4	91.27703	89.42703	135.5	137	7.28	6.22	53.727	45.401
MAS 109	100	95.6	30.95238	29.10238	127.5	131	3.98	3.96	31.216	30.229
MAS 868	86.25	87.05	90.89957	89.04957	139.5	146	6.36	4.6	45.591	31.507
qRT(1+7)-5	98.5	95.9	93.5	91.65	131.5	133	4.64	5.76	35.285	43.308
QRT (1+7)-8	100	100	91.43986	89.58986	134	140	5.36	5.64	40.000	40.286
OYT 58	97.2	97.2	91.06744	89.21744	130.5	137.5	6.42	5.86	49.195	42.618
SEL 128	100	100	86.22115	84.37115	132	137.5	6.88	7.36	52.121	53.527
Nellore Sona	98.65	97.95	94.07609	92.22609	133.5	138.5	6.78	5.32	50.787	38.412
IET 21594	95.35	95.35	91.56672	89.71672	128	131.5	8.52	6.2	66.563	47.148
IR 68888 B	96.6	96.6	79.04578	79.58939	130.5	129.5	4.62	5.12	35.402	39.537
IR 68897 B	100	100	76.63348	74.78348	128	130.5	4.26	1.82	33.281	13.946
IR 58025 B	91.35	91.35	62.91345	65.35	138.5	141	5.2	6.4	37.545	45.390
IR 79156 B	96.6	96.6	90.58826	88.73826	139	141	7.4	5.9	53.237	41.844
25P25	99.3	93.14	87.21122	74.15	135.5	137	5.58	7.2	41.181	52.555
PHB 71	100	92	91.27703	77.41208	135.5	137.5	5.9	7.2	43.542	52.364

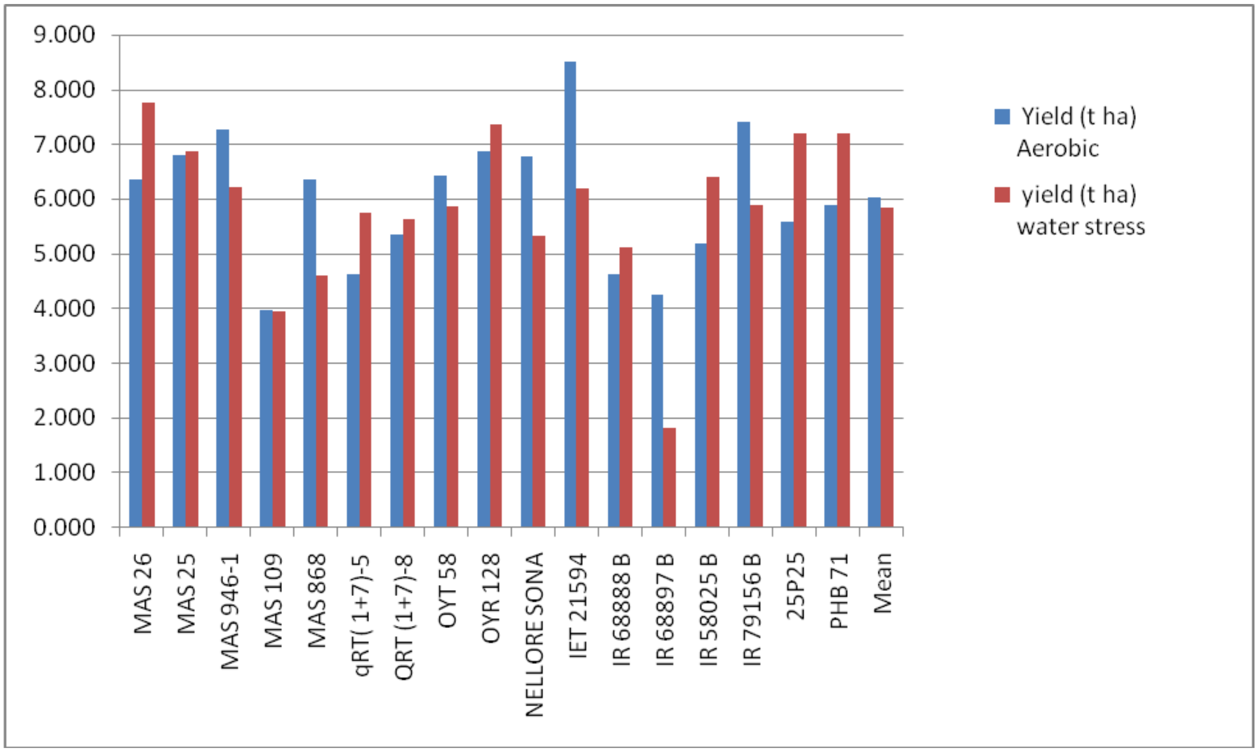

Figure 1 : Yield (t ha^{-1}) of selected genotypes under aerobic and water stress situation