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Identification of Multi Trait QTL / Gene Pyramided Genotypes Superior for Grain Yield under Low Moisture Stress in Rice (*Oryza sativa* L.)

G. Uday and Shailaja Hittalmani
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru-560 065

Abstract

Sixty multitraits QTL pyramided genotypes of F_8 generation, parents (RB 6, QRT25) and check (MAS 946-1) were evaluated for grain yield and related traits under aerobic and low moisture stress during dry season of 2015. Experiment was conducted in randomized complete block design with two replications. The mean performance of the parents varied and was highly significant (P<0.001) for grain yeild plant^{-1} under both moisture treatments. Analysis of variance showed high significance for genotype mean sum of squares under both moisture regimes. Moderate to high GCV, PCV coupled with high heritability was observed for the pyramids revealing possible contribution of additive gene action among QTLs controlling deep roots (*qRT*) and water use efficiency (*qWUE*). Eight pyramided genotypes were superior for grain yield plant^{-1}, when compared to check and parents under aerobic and low moisture stress. The thee QTL pyramided genotype 36 possessing QTL for deep rooting (*qRT2),* root volume *(qRT7)* and water use efficiency *(qWUE2)* was superior to MAS 946-1 for grain yield under low moisture stress. This genotype is worth testing in multiple locations for its suitability as a cultivar in low moisture rice cultivation.

Rice (*Oryza sativa* L.) is the second highest worldwide producing cereal crop and rice is the most important grain for human consumption. It is cultivated in several ecosystems like upland, rainfed lowland, flood prone and irrigated systems. The present day global shortage of water is a great hindrance for rice production as rice require high amount of water (5000 liters *per* kg of rice production). Water scarcity is escalating and irrigation is becoming a costly input. According to various estimates, 40 per cent increase in production of rice is required by 2030 to satisfy the food demands of growing population, from less land, with less water, less labour and less inputs (Khush, 2005). The demand for rice will be ever increasing, so developing varities that can yield well on marginal soils with limited water supply accompanied with enhanced productivity is essential and inevitable. To meet this growing demand, it is required to increase the productivity levels of rice in stress prone ecosystems by combating biotic and abiotic stresses.

Among abiotic stresses, drought (low moisture stress) is one of the primary constraints depressing the yield level and destabilizing rice production. Drought tolerance is considered as a polygenic trait controlled by genes / QTLs having varying effects and it is dependent on drought timing and severity (Bernier *et al.,* 2008). It has been demonstrated that drought tolerant upland rice varieties can also be bred by directly selecting for grain yield in stress environments (Bernier *et al.*, 2008). However, existing procedure for breeding drought tolerance is to develop pyramided genotype having multiple QTLs / genes controlling deep rooting, high water use efficiency, osmotic adjustment and other drought responsive traits. The present study was carried out with an objective of identifying superior pyramided genotypes out performing for grain yield under low moisture stress.

The plant material for the study consisted of 60 F_8 multitrait pyramided genotypes, derived from crossing divergent parental lines *viz*., QRT 25 (derived from cross IR64 X Azucena, are drought tolerant, high water use efficient, high yielding with medium bold grain quality) and RB-6 (derived from cross RpBio X BL122, resistant to blast and bacterial leaf blight disease with fine grain quality), their parents and check (MAS-946-1). The F_1 were confirmed using parental polymorphic microsatellite markers and forwarded. From F_3 to F_8 pyramids carrying QTLs for deep rooting, root volume, root thickness and high water use efficiency (*qRT2*, *qRT7*, *qRT9* and *qWUE2*) in QTL combination were selected through marker assisted selection using trait specific micro-satellite markers (Chandrashekar, 2013)

The field experiments were conducted during dry season of 2015, in the experimental plots of Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore. The 60 F_8 generation pyramided genotype along with their parents and checks were evaluevated under aerobic condition (control plot) and low moisture stress at reproductive stage (stress plot). The experimental layout was in Randomized complete block design (RCBD) with two replications. The cultural operation was carried out as per UAS, package of practice. Low moisture stress was imposed by withholding irrigation for 15 days at reproductive stage (75- 90 days after sowing). The data were recorded on the plant height (PH), Days to flowering (DF), Days of maturity (DM), Productive tillers plant^{-1} (PT), Panicle length (PL), Panicle exsertion (PE), Spikelet fertility (SF), and Grain yield per plant (GYP^{-1}) on ten randomly selected plants under both control and stress condition.

Average for quantitative traits were computed based on ten randomly selected plants were used for statistical analysis. Analysis of variance was carried out for each condition separately in order to assess the variability among the genotypes following RCBD as given by Panse and Sukhatme (1967). Genetic variability parameters were estimated by using standard formula. Test for significance between parents for quantitative traits was performed using *SAS 9.2* version.

Mean values of the parents for selected quantitative characters were different under low moisture stress as compared with the aerobic condition (Table I). Low moisture stress at reproductive stage showed reduction in plant height, productive tillers and grain yield plant^{-1} for both parents. Similar results were observed by (Uday *et al.*, 2016). Plant height reduced under low moisture stress due to unavailability of moisture at critical growth stage and it directly affecting biomass of plant. Low number of filled spikelets panicle^{-1} and panicle exsertion leads to reduced spikelet fertility which in turn exhibited reduced grain yield in low moisture stress as compared aerobic condition (Jongdee *et al.*, 2002).

Test for significance for parental means indicated that parents RB 6 and QRT-25 were highly significant for eight quantitative trait recorded under both aerobic and low moisture stress condition.

The analysis of variance for grain yield and drought related traits observed under aerobic and low

TABLE I

Estimation of parental means and range of pyramided genotypes under aerobic and low moisture stress conditions

Characters	Mean								Range			
	RB 6 (P_1)		QRT 25 (P_2)		P_1 vs. P_2		MAS 946-1 (Check)		Min		Max	
	C	S	C	S	C (Pr<t)	S (Pr<t)	C	S	C	S	C	S
PH(cm)	64.5	60.3	80.8	75.5	0.001	0.001	65.1	60.2	49.0	48.7	94.0	95.1
DF(days)	95.0	101.0	88.0	92.0	0.010	0.004	94.0	98.0	80.0	85.0	102.0	105.0
DM(days)	126.0	132.0	118.0	120.0	0.010	0.002	120.0	128.0	107.0	117.0	135.0	131.0
PT	19.0	16.0	15.0	13.0	0.040	0.008	18.0	15.0	12.0	8.0	25.0	19.0
PL(cm)	15.0	14.6	19.2	18.5	0.001	0.002	17.5	15.5	14.3	14.1	23.3	23.3
PE(cm)	-3.0	-6.5	1.5	-0.5	0.035	0.001	-0.8	-4.5	-6.8	-9.8	5.2	2.2
SF (%)	64.5	45.6	80.5	68.4	0.001	0.016	78.5	57.0	52.03	45.02	97.5	78.39
GYP^{-1}(g)	18.8	10.5	28.5	18.5	0.090	0.001	24.5	13.5	18.16	10.3	40.12	33.9

C: control plot/ Aerobic condition S: Low Moisture Stress moisture stress condition showed highly significant genotype mean sum of squares (Table II). The results showed clearly wide genetic differences for all grain yield and its related traits, this also indicating the presence of wide range of genetic variability in plant material. This indicates further scope for selection of desired plant traits.

Moderate phenotypic co-efficient of variance (PCV) and genotypic co-efficient of variance (GCV) estimates with high heritability broad sense (h^2) were noticed for characters such as plant height, productive tillers under aerobic condition. Similarly under low moisture stress high GCV and PCV with high heritability broad sense was observed for grain yield plant^{-1} (Table III). The results indicate high heritability values resulted in high values of expected genetic advance as per cent mean (GAM). This high heritability coupled with high GAM indicates the effectiveness of selection for aforesaid characters in drought condition (Courtois *et. al*., 2003). Panicle length, panicle exertion, spikelet fertility and grain yield plant^{-1} having high heritability coupled with high GAM under moisture stress has been considered as important characters in drought tolerance breeding. The results indicated that possible contribution of additive gene action of pyramided genes/QTLs for the expression of traits (Selvi *et al*., 2016)

The pyramided genotypes 34, 35, 50, 20 and 13 carrying QTLs (*qRT2*, *qRT7*, *qRT9* and *qWUE2*) in different combinations (Chandrashekar, 2013) were

TABLE II

Analysis of Variance for Grain Yield and Related Traits under Aerobic and Low Moisture Stress Conditions

Source of Variations	df		Mean sum of squares							
			PH (cm)	DF(days)	DM(days)	PT	PL (cm)	PE(cm)	SP (%)	GYP^{-1} (g)
Replications	1	C	2.91	0.28	6.67	0.67	1.16	0.31	1.57	5.12
		S	0.99	1.78	4.10*	3.50	1.25*	2.33	5.52	2.79
Genotypes	62	C	289.66***	53.00***	69.07***	14.85***	6.96***	11.39***	195.46***	54.2***
		S	273.81***	43.25***	26.12**	8.28***	8.74*	12.61*	213.17**	62.83**
Error	62	C	26.07	3.34	0.90	1.85	0.43	2.19	30.96	0.90
		S	7.06	10.64	0.33	1.37	0.35	1.02	20.71	0.77

* Significant @ P<0.05; ** Significant @ P<0.01; *** Significant @ P<0.00. C: control plot/ Aerobic condition S: Low Moisture Stress

TABLE III

Genetic variability parameters for grain yeild and its related traits under aerobic and low moisture stress situations

Characters	Mean ± SE		GCV		PCV		h^2		GAM	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
PH (cm)	71.20 ± 3.58	70.42±1.90	16.12	16.45	17.64	16.88	83.50	95.00	30.34	33.0.
DF	91.93 ± 1.28	96.41±2.34	5.42	4.18	5.77	5.38	88.20	60.50	10.84	6.70
DM	121.08 ± 2.62	127.98±0.56	4.33	2.86	5.32	2.90	66.30	97.50	7.26	5.82
PT	16.11 ± 0.95	14.20±1.14	15.82	12.72	17.92	15.03	77.90	71.60	28.76	22.17
PL(cm)	19.03 ± 0.46	18.50±0.65	9.49	11.17	10.10	11.62	88.30	92.30	10.38	22.10
PE	1.11 ± 1.03	5.27±0.72	191.70	46.37	232.94	50.30	67.70	85.00	325.01	88.06
SF (%)	75.19 ± 3.90	61.81±3.26	12.06	15.91	14.15	17.54	72.60	82.30	21.17	29.74
GYP^{-1} (g)	28.29 ± 0.66	22.87±1.04	13.23	25.75	8.55	26.07	96.70	97.60	36.95	52.40

TABLE IV

Grain yield potential for selected top performing pyramids under aerobic and low moisture stress situations

Characters		Pyramided genotypes					Parental lines		Check Variety
		34	35	50	20	13	RB 6 (P_1)	QRT 25 (P_2)	MAS 946-1
PH (cm)	C	69.00	66.00	65.50	87.50	67.00	64.5	80.8	65.1
	S	68.44	61.34	64.99	86.49	66.71	60.3	75.5	60.2
DF (days)	C	87.00	95.00	91.00	86.00	94.00	95.0	88.0	94.0
	S	95.00	100.00	93.00	92.00	96.00	101.0	92.0	98.0
PL (cm)	C	19.10	48.84	20.11	19.05	20.30	15.0	19.2	17.5
	S	19.56	18.29	19.64	18.45	20.36	14.6	18.5	15.5
PE(cm)	C	-4.22	-1.33	-3.10	4.75	-3.05	-3.0	1.5	-0.8
	S	-4.87	-3.53	-7.35	-0.61	-5.55	-6.5	-0.5	-4.5
SF (%)	C	83.47	85.55	86.04	91.26	78.26	64.5	80.5	78.5
	S	77.27	70.55	70.79	71.60	75.26	45.6	68.4	57.0
GYP^{-1} (g)	C	40.12	35.89	37.16	34.41	33.90	18.8	28.5	24.5
	S	33.89	32.23	28.99	28.91	28.10	10.5	18.5	13.5

C: Control Plot/ Aerobic condition S: Low Moisture Stress.

found to be superior to their parents and check in terms of their ability to produce high grain yield plant^{-1} under aerobic and low moisture stress condition (Table IV). The pyramided genotype 36 (*qRT2+qRT7+qWUE2)* carrying QTL for deep rooting (*qRT2)*, root volume *(qRT7)* and water use efficiency *(qWUE2)* in combination performed well over MAS 946-1 under both moisture regimes for panicle length, panicle excertion, spikelet fertility and grain yield plant^{-1}. These pyramided genotypes are worth testing in multiple locations for conferring its performance for stability and adaptability for direct commercial exploitation as cultivar for low moisture stress condition in rice cultivation.

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