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Short Communication

Effect of QTLs controlling grain yield under drought stress in the genetic background of ADT45 rice variety

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Abstract

Drought is a major production constraint in rain-fed upland and rainfed lowland ecosystems of rice cultivation. A set of two backcross inbred lines (BILs) harboring mega effect QTLs controlling grain yield under stress were developed in the genetic background of ADT 45 through marker assisted selection (MAS) and evaluated for drought tolerance at reproductive stage under rain out shelter. Background selection of BILs showed highest recovery (90%) of recipient genome in the BIL harboring three major QTLs from Apo a tolerant donor. Significant differences were observed among the BILs and parents for grain yield and its contributing traits under both severe moisture stress and well irrigated conditions when compared to ADT 45. The BIL harboring three major QTLs, *DTY* (2.2+3.1+8.1) [QTLs for yield under stress on chromosome 2,3 and 8] performed better and showed increased values for grain yield, plot yield, spikelet fertility and harvest index than the BIL harboring 2 major QTLs *DTY* (3.1+8.1), which shows pyramiding of more number of QTLs may enhance the grain yield under stress. Both the BILs harboring two and three major QTLs recorded lesser Drought Susceptible Index under severe moisture stress.

Key words: Drought resistance, yield under stress, QTLs, marker assisted selection

Rice is the second most important cereal food crop of the world, being cultivated in all the continents except Antarctica, over an area of more than 150 million ha, but most rice production takes place in Asia [1]. Drought is considered as the major constraint limiting rice production worldwide. Mitigating drought in rainfed rice ecosystems contribute to food security of the country. Grain yield under drought stress is a complex quantitative trait whose heritability is thought to be low relative to yield in non stress environments, reducing selection efficiency [2]. Hence much effort has been focused on the genetic analysis of secondary traits such as root system architecture, leaf water potential, panicle water potential, osmotic adjustment and relative water content [3]. However, these traits rarely have higher broad-sense heritability than yield under drought stress and are often not highly correlated with it [4]. Studies at IRRI have shown moderate to high heritability of grain yield under drought [5] thus opening area for direct selection for grain yield under stress rather than selecting for secondary traits. Further, direct selection for grain yield under drought has been reported to be effective [6] and the feasibility of combining high yield potential with good yield under drought has been demonstrated beyond doubt. By employing direct selection for grain yield under drought, several promising breeding lines for rainfed lowlands and rainfed uplands have been identified recently [7]. The identification of QTLs with major effect on grain yield raises new hopes of improving grain yield under drought through marker-assisted breeding. In the present experiment we aimed at the introgression of the QTLs associated with yield under drought stress from the tolerant variety Apo into ADT 45, a major elite variety but susceptible to drought situations.

The material for the study comprised of a set of backcross inbred lines (BILs) of ADT45 which were introgressed with QTLs for yield under stress (located on chromosomes 2, 3 and 8) in different combinations.

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The QTLs were originally derived from Apo, an upland *indica* cultivar. Recombinant inbred lines derived between IR64 and Apo (F_4 generation) harboring the major effect QTLs controlling for yield under stress were used as donors for introgression into ADT45 through MAB. F_1s were generated between ADT45 and RILs (IR64 x Apo) and backcrossing was carried out to generate BC_1F_1 and selfed till BC_1F_3 (Fig. 1). The experiment was carried out at Paddy Breeding Station, Centre for Plant Breeding and Genetics, TNAU, Coimbatore. The BILs were evaluated during *Kharif'* 2013 for their drought responses under rain-out shelter conditions along with well-irrigated controls. The three SSR markers namely, RM 71 (chromosome 2; 8.8 Mb), RM 520 (chromosome 3; 30.9 Mb), RM 256 (chromosome 8; 24.2 Mb), exhibiting polymorphism between ADT45 and APO were used for foreground selection to introgress the target QTLs *viz*., *DTY 2.2, DTY3.1 and DTY8.1* (QTLs for yield under stress) into ADT45. Two genotypes were found to possess the various combinations of target QTLs. One was homozygote for two QTLs *DTY*(3.1+8.1) and another genotype was homozygote for all three QTLs *DTY* (2.2 +3.1+8.1). The two and three QTL harbouring lines were selfed to develop BC_1F_3. The selected BC_1F_3 lines were evaluated for their performance under both well-watered and drought conditions (under rain-out shelter) along with the parents and a check variety Anna 4. Recommended crop production and protection practices were followed to raise a healthy crop. Regular irrigation was given until 67 DAS and afterwards irrigation was completely stopped for the lines planted under rain-out shelter conditions. Depleting Soil moisture levels in drought experiment was monitored by installing IRROMETER™ at two different depths *viz*., 30 cm, and 15 cm in stressed blocks and readings were recorded in terms of - kilobars and is represented in Fig. 2. The Drought Susceptibility Index (S) of all the genotypes was calculated using the suggested formula [8].

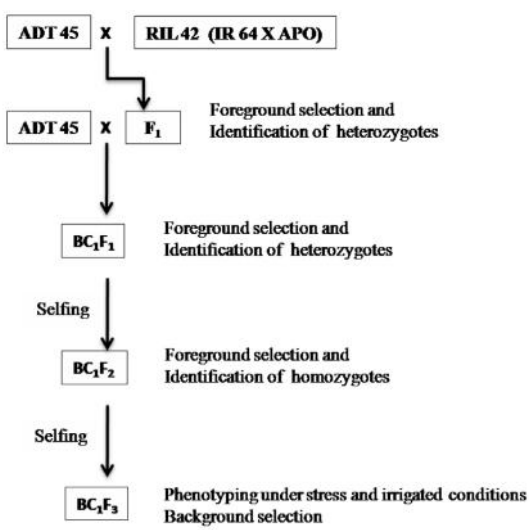

Fig. 1. Introgression of DTY QTLs

Comparison of mean performances of parental lines and BILs along with the check variety under well-watered and drought stress conditions clearly showed that the introgression of mega effect QTLs derived from the tolerant parent Apo *viz*., *DTY*2.2, *DTY*3.1 and *DTY*8.1 was found to be effective in increasing grain yield and contributing characters under stress conditions in the genetic background of ADT45. BILs were vigorous when compared to parents and check. The BIL, CB13-902-238-1 harboring three major QTLs performed better and showed increased values for most of the characters especially for spikelet fertility, harvest index, plot yield and grain yield per plant, this particular BIL also showed more recovery of recipient genome (ADT 45) which is a localy adapted high yielder (Table 1). Days to 50% flowering had no significant difference between control (81.5 days) conditions and severe stress condition (80.5 days). This kind of observation clearly shows that genotypes were not tending to escape stress but were tolerant. As evident from Table 2, the drought susceptible recurrent parent ADT45 recorded least values for all the characters, where as donor parent Apo and local check Anna 4 showed moderate values, but still they were poor performers when compared to QTL introgressed BILs. QTL related to heading date (HD) have been reported near *DTY*3.1 [9]. BILs were taller than ADT 45 under control conditions but they showed reduction in height under stress conditions. This observation has already been reported [10] that relationship between plant height and drought resistance was due to the presence of *sd-1* gene which often associated with other component traits such as high tillering and shallow rooting due to their pleiotrophic effects. BILs were found to have increased spikelet fertility, harvest index, plot yield and grain yield per plant. These results are

Table 1. Recurrent parent genome recovery of BILs

Genotypes	A (%)	B (%)	H (%)
*DTY*3.1+8.1	75	10.2	14.8
*DTY*2.2+3.1+8.1	90	9.9	0.1

A=ADT45 genome; B=Apo genome; H=heterozygous region; *DTY*3.1+8.1=BIL with 2 QTLs on 3rd and 8th chromosome; *DTY*2.2+3.1+8. 1=BIL with 3 QTLs on 2nd, 3rd and 8th chromosome

Table 2. Mean values of parents, check and BILs under contrast water regimes

Traits	Parents				Check		BILs			
	ADT45		APO		ANNA 4		*DTY*3.1+8.1		*DTY*2.2+3.1+8.1	
	s	c	s	c	s	c	*s*	*c*	*s*	*c*
DFF	83.50	91.0	87.00	91.5	91.50	95.0	81.00	80.5	82.00	80.5
PH	66.65	76.35	74.35	109.5	81.35	89.65	63.65	85.50	59.80	80.20
NOP	8.50	18.65	5.00	19.00	9.00	26.00	8.17	18.00	9.00	21.15
TGW	16.80	20.11	22.00	23.07	22.50	24.14	23.55	28.54	23.20	28.10
SF	34.87	90.20	59.50	86.93	46.81	84.74	84.83	97.03	91.21	94.21
HI	0.045	0.39	0.160	0.31	0.180	0.36	0.235	0.43	0.280	0.45
PY	8.420	463.3	35.50	599.8	28.80	720.2	40.75	723.0	76.28	865.0
Y/P	1.665	33.60	7.500	43.87	5.57	41.87	8.370	43.65	11.25	61.99

DFF = days to 50% flowering; PH = plant height cm; NOP = number of panicles; TGW = thousand grain weight g; SF = spikelet fertility; HI = harvest index; PY = plot yield g; Y/P= yield per plant in g; *DTY*3.1+8.1: BIL with 2 QTLs on 3rd and 8th chromosome; *DTY*2.2+3.1+8. 1 = BIL with 3 QTLs on chromosomes 2, 3rd and 8th; under stress; c=under controlled condition

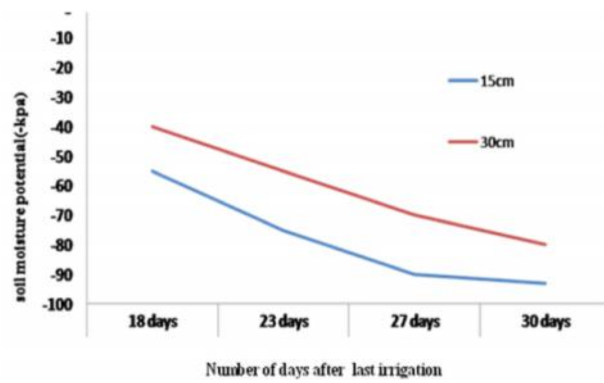

Fig. 2. Soil moisture potential after stress induction

in confirmation with reports [11] that under stress conditions, RM 256 on chromosome 8 showed putative linkage with the QTLs of single plant yield and root volume and also pleiotrophic effects of QTLs conferring drought tolerance on grain yield and their contributing traits under moisture stress [12]. Under well-watered conditions, both the BILs harboring 2 QTLs (CB13-902-38-1) and 3 QTLs (CB13-902-238-1) showed good vigour, spikelet fertility and harvest index. Particularly, the BIL harboring 3 major QTLs had the highest value (28.10 g) for 1000 grain weight and grain yield (Table 2). Increased 1000 grain weight of BILs under both control and stress conditions may be attributed to bolder grains, a character donated by Apo. There was no significant reduction in flowering duration during stress. Both the genotypes possessed DTY3.1 which has been reported to affect flowering and grain yield under stress conditions. There was up to 80 percent yield reduction observed under severe moisture stress conditions as already reported by several workers [3,13-15]. Percent gain of BILs for various yield related traits during control condition over severe stress condition is given in Table 3. Over all performance of the BILs harboring QTLs *DTY*2.2, 3.1 and 8.1 is advantageous over susceptible recurrent parent. Drought Susceptibility Index (DSI) was calculated for the BILs and parental lines based on their grain yield per plant under severe moisture stress in comparison to yield under control conditions. Parents and the check variety Anna 4 had higher values of DSI when compared to DSI values of the BILs which had lesser DSI values (0.808 in case of 2 QTL line (CB13-902-C-38-1) and 0.819 in case of 3 QTL line (CB13-902-C-238-1) respectively (Fig. 3). For areas where severe stress is a recurrent phenomenon, selection of

Table 3. Percent gain of traits in control conditions over stress conditions among BILs

Traits	*DTY*3.1+8.1	*DTY*2.2+3.1+8.1
DFF	–0.552	–1.863
PH	25.56	25.44
NOP	54.61	57.45
TGW	17.47	17.44
SF	12.58	3.190
HI	45.60	37.64
PY	94.36	91.18
Y/P	80.82	81.85

DFF= days to 50% flowering; PH= plant height cm; NOP= number of panicles; TGW= thousand grain weight g; SF= spikelet fertility; HI =harvest index; PY= plot yield g; Y/P= yield per plant in (g). *DTY*3.1+8.1: BIL with 2 QTLs on 3rd and 8th chromosome; *DTY*2.2+3.1+8. 1=BIL with 3 QTLs on 2nd, 3rd and 8th chromosome; *DTY*3.1+8.1=BIL with 2 QTLs on 3rd and 8th chromosome; *DTY*2.2+3.1+8. 1=BIL with 3 QTLs on 2nd, 3rd and 8th chromosome.

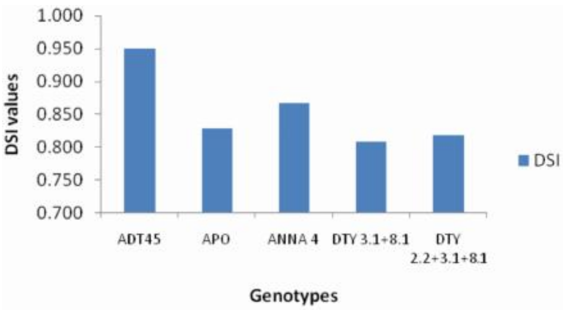

Fig 3. Comparison of drought susceptible index (DSI) values of parents, Check and BILs

genotypes with low DSI can be useful. There is considerable evidence [16] to support the hypothesis that few QTLs exist in rice which have large effects on grain yield and/or flowering that are unique to particular hydrological conditions. From our study it is much evident that QTLs have effect on yield and all the yield contributing traits under both severe moisture stress and control conditions. Though there was 80-90% yield reduction under severe moisture stress conditions when compared to well irrigated, the QTL possessing lines over performed susceptible parents and check which confirms the advantage of these QTL introgression.

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