Field Crops Research 163 (2014) 119–131

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Major QTL for enhancing rice grain yield under lowland reproductive drought stress identified using an *O. sativa/O. glaberrima* introgression line

Surapaneni Saikumar[a,b,c,*], P. Kalmeshwer Gouda[d], A. Saiharini[a], C. Mohan Kumar Varma[e], O. Vineesha[f], G. Padmavathi[c], V.Venoy Shenoy[a]

[a] Barwale Foundation, Barwale Chambers, #3-6-666, Street No. 10, Himayathnagar, Hyderabad 500029, A.P., India
[b] Department of Genetics, Osmania University, Hyderabad, A.P., India
[c] Directorate of Rice Research, Rajendranagar, Hyderabad 500030, A.P., India
[d] Monsanto India Limited, Udaipur, Rajasthan, India
[e] Bayer (South East Asia) Pte Ltd, 108 Pasir Panjang, Singapore 118535, Singapore
[f] CDFD, Hyderabad 500001, A.P., India

ARTICLE INFO

Article history:
Received 15 January 2014
Received in revised form 14 March 2014
Accepted 18 March 2014
Available online 24 April 2014

Keywords:
Rice
Drought
QTL
Grain yield
Canopy temperature

ABSTRACT

Water stress is a major abiotic stress limiting the rice production and yield stability in rainfed conditions and getting worse with the predicted global climatic change. A Backcross inbred line (BIL) population derived from Swarna/WAB 450-I-B-P-157-2-1 was screened for grain yield under reproductive stage drought stress and irrigated conditions during DS2013, WS2012 and DS2012. A major qDTY3.2 with large and consistent effect on grain yield was mapped on chromosome 3 flanked by RM14303 and RM22 across three seasons under both stress and control conditions. qDTY3.2 explained a phenotypic variance of 29.5%, 18.8% and 31.8% under drought stress during DS13, WS12 and DS12, respectively. Apart from grain yield, qDTY3.2 is also account for variation in canopy temperature during flowering and seedling shoot dry weight and drought recovery under stress conditions. Lines with QTL showed a clear grain yield advantage over lines without QTL under both stress and control conditions. Due to the consistent effect of qDTY3.2 across diverse environments and varied level of stresses makes it an appropriate candidate for MAS. Introgression of such genomic regions in to elite drought susceptible backgrounds can lead to enhancement of grain yield level to a greater extent.

1. Introduction

Rice, is one of the most important food crops for Africa and Asia, plays an irreplaceable role in national food security. Globally, majority (70%) of rice is contributed from irrigated ecosystems, where yield increase is now getting stagnated (Peng et al., 1999). However, rainfed ecosystem contributes only quarter to the total rice production even though it occupies 50% of the total rice area in the world, which relies solely on rainfall rather than irrigation (Maclean et al., 2002). Hence, rice is vulnerable to the increased frequency of drought stress under predicted climate change. Changes in rainfall and its distribution may cause more frequent and intensive drought and flood, which are major factors that limit rice yield. In Asia alone, about 34 million ha of rainfed lowland and 8 million ha of upland rice (Huke and Huke, 1997) are subject to frequent drought stress of varying intensities at different stages every year. Water-deficit often combined with high temperature stress is the main abiotic factor limiting crop-plants productivity and global food security (Boyer, 1982). Drought is the major environmental constraints to rice productivity in rainfed areas (Farooq et al., 2009; Serraj et al., 2009). Rice is highly sensitive to drought stress during reproductive stage; even moderate stress can result in drastic reduction in grain yield (Hsiao, 1982; O'Toole, 1982; Pantuwan et al., 2002; Lanceras et al., 2004; Venuprasad et al., 2009b). At all stages of rice growth and development, drought is the major stress (Bimpong et al., 2011). To meet the ever-growing demand for rice by 2030, a significant increase of at least 35%

* Corresponding author at: Barwale Foundation, Barwale Chambers, #3-6-666, Street No. 10, Himayathnagar, Hyderabad 500 029, India. Tel.: +91 40 2766 5871 73; fax: +91 40 2766 5874; mobile: +91 9908097908.
E-mail addresses: ssaikumar27@gmail.com, saikumar@barwalefoundation.org (S. Saikumar).

http://dx.doi.org/10.1016/j.fcr.2014.03.011
0378-4290/

in yield is needed (Bouman et al., 2007). Hence development of drought tolerant cultivars is the feasible and effective approach to cope with the destabilizing effects of drought stress in rainfed conditions. However, Progress in breeding for drought resistance has been slow (Fukai and Cooper, 1995). Earlier, the lack of effective selection criteria for traits related to drought tolerance and low heritability of GY under stress were cited as major reasons for slow progress in breeding (Ouk et al., 2006). Direct selection for grain yield under stress (Venuprasad et al., 2007; Kumar et al., 2008) is proved to be an effective and efficient approach rather than selection based on secondary traits such as root architecture, leaf water potential, panicle water potential, osmotic adjustment, and relative water content (Fukai et al., 1999; Price and Courtois, 1999; Jongdee et al., 2002; Pantuwan et al., 2002). Advances in molecular marker technology have enabled fast track improvement of crop plants in recent years. To unveil the genetic basis of a complex trait such as grain yield under drought, it is a prerequisite to identify the QTL with large effect on grain yield (Vikram et al., 2011), which are suitable candidates for marker-assisted breeding (MAB). From the past decade, several QTL have been mapped for GY under drought stress, out of them only ten such QTL were reported to have large and consistent effect on grain yield under both upland and lowland ecosystems located on rice chromosomes 1, 2, 3, 4, 6, 9, 10 and 12. qDTY1.1 (Kumar et al., 2007), qDTY12.1 (Bernier et al., 2007), qDTY2.1 and qDTY3.1 (Venuprasad et al., 2009a), qDTY6.1 (Venuprasad et al., 2012), qDTY3.2 (Yadaw et al., 2013) and qDTY2.2, qDTY4.1, qDTY9.1 and qDTY10.1 (Swamy et al., 2013). These QTL will be useful in Crop genetic improvement and understanding the genetic and physiological basis for environmental stresses such as drought. For a complex trait such as GY under drought, marker-assisted selection (MAS) could be an efficient strategy to improve current cultivated drought-susceptible varieties (Asins, 2002; Bernier et al., 2007).

Genetic variation is considered as the basis of crop breeding. In pursuit of higher yield, breeding programs were carried between genetically similar elite parents, which led to the narrowed genetic base in rice, which renders modern cultivars more vulnerable to a series of biotic and abiotic stresses (Ali et al., 2006). Therefore, it is imperative to promote the exploitation of distant wild resources for incorporating alien genetic variation for resistances to diverse stresses into modern cultivars (Biao-lin et al., 2011). However, the reports on utilization of wild relatives and unadapted germplasm in drought breeding and the release of drought resilient cultivars are limited (Kalmeshwer et al., 2012; Swamy and Kumar, 2012). Poor agronomic performances of wild species has limited their utility in crop breeding. Wild relatives like *viz.*; *Oryza glaberrima*, *O. rufipogon* and *O. meridionalis* are excellent resources for tolerances to biotic and abiotic stresses and several studies recently demonstrated their role in improvement of stress tolerance (Bimpong et al., 2011; Kalmeshwer et al., 2012; Moncada et al., 2001; Zhang et al., 2006). Therefore, utilization of distant wild resources for incorporating genetic variation is found to be one of the available options for developing modern cultivars tolerant to diverse stresses.

'New Rice for Africa' (NERICA) genotypes developed from the cross between Asian rice (*Oryza sativa*. L) and African rice (*O. glaberrima* Stued.) by Africa Rice Center (WARDA: West Africa Rice Development Association), has wide range of adaptability to the rainfed lowland as well as upland ecosystems. However, information is limited on the grain yield performance of lowland NERICA genotypes (Sie et al., 2008). Recent reports indicates that yield levels of some upland genotypes were similar to that of lowland semi dwarf genotypes in lowland and irrigated conditions and yield better under moisture limiting environments (Bouman et al., 2005; Atlin et al., 2006; Haefele et al., 2008). Thus, the upland rice genotypes adapted to a wide range of water availability may serves as donors for drought tolerance and improve lowland rice productivity.

In the present study, we report the identification of qDTY3.2 for grain yield under both lowland drought stress and irrigated conditions from BILs derived from rice genotypes Swarna/WAB 450-I-B-P-157-2-1. These BILs were evaluated both under irrigated and lowland drought stress at reproductive and seedling stage to identify QTL for tolerance to moisture stress from WAB 450-I-B-P-157-2-1.

2. Materials and methods

2.1. Location

The study was carried out at experimental farm of the Barwale Foundation, Maharajpet, Hyderabad, India located at latitude of 17°24′ N and longitude of 78°12′ E, and an altitude of 536 m above mean sea level. The soil type was characterized as clay loam with high pH (Table 1).

2.2. Plant material

Swarna, a semi-dwarf high yielding indica line with excellent yield potential and quality, thrives well under irrigated and favorable rainfed lowland and occupies around 12% of the total rice production area in India. However, Swarna is highly susceptible to moisture stress (Venuprasad et al., 2009a) "WAB 450-I-B-P-157-2-1" is an upland ecotype developed by African rice center (WARDA), known for its drought tolerance, deep root, early vigor, weed competitiveness, pest or disease resistance and other grain quality attributes with yield advantage over *O. glaberrima* and *O. sativa*, its parents (Africa Rice, 2011). Swarna (female) was crossed with WAB 450-I-B-P-157-2-1. The true F_1s were then backcrossed with Swarna as recurrent female parent. The obtained BC_1F_1s were then advanced to BC_1F_6 by 5 subsequent generations of selfing for mapping QTL. The BILs so obtained were evaluated for drought response at seedling and lowland reproductive stage stress. Along with the mapping population, parents and popular checks like Vandana, N22 (drought tolerant), IR64 and MTU1010 (Susceptible check) were used for yield and morphological comparisons.

2.3. Phenotyping of BILs

A set of 202 BILs were evaluated in the experimental farm of Barwale Foundation, Hyderabad, India, under rainfed stress and irrigated condition simulating or representing target population environment (TPE).

2.3.1. Field experiments

Six field experiments were conducted during 2012 and 2013(dry season and wet season) with varied level of moisture stress. They comprised three lowland non-stress trials (one each during DS 2012, DS 2013 and WS 2012), two lowland managed stress trials (one each during DS 2012 and DS 2013) and one lowland natural stress (rainfed) trials (WS 2012). All the experiments were laid out as RCBD designs with two replications. A plot size of 1.2 m^2 was used for lowland trials.

2.3.1.1. Control trials. 25-Day old seedlings were transplanted in to the main field. One seedling was transplanted per hill at a spacing of 20 cm between hills as well as rows. After transplanting, approximately 5 cm of standing water was maintained in the field until draining before harvest. Inorganic NPK fertilizer was applied at the rate of 100–50–50 kg ha^{-1}. Weeds and insect pests were controlled chemically in order ensure a healthy crop.