Field Crops Research 175 (2015) 26–36

Contents lists available at ScienceDirect

Field Crops Research

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

Genotypic variation in grain yield and flowering pattern in terminal and intermittent drought screening methods in rainfed lowland rice

T. Monkham[a], B. Jongdee[a,*], G. Pantuwan[b], J. Sanitchon[a], J.H. Mitchell[c], S. Fukai[c]

[a] Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand
[b] Bureau of Rice Research and Development (BRRD), Rice Department, Bangkok, Thailand
[c] The University of Queensland, School of Agriculture and Food Sciences, Brisbane 4072, Australia

ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form 31 January 2015
Accepted 2 February 2015

Keywords:
Water deficit
Rice maturity group
Drought resistance
Delay in flowering
Aerobic rice
Intermittent stress

ABSTRACT

Rainfed lowland rice in the Mekong region is mostly grown in drought-prone areas, and drought resistant varieties could be selected using either terminal drought (severe water stress after flowering) or intermittent drought (frequent mild stress) screening. Delay in flowering is considered as a putative trait for selection of drought resistant genotypes, and its effectiveness as an indirect selection trait and its association with genotype's flowering duration, i.e. the time taken from the first to last flower in a plot, was evaluated under the two drought screening methods. These screening methods together with flood control were used at two locations, Chum Phae and Ubon in north-east Thailand using a total of 70 genotypes with different growing duration. Delay in flowering was estimated for the two drought screening methods and flowering of individual panicles within a plot was recorded to determine flowering duration of each genotype in the flood and terminal drought conditions.

Mean reduction in grain yield was 52–55% under the terminal drought screening while it was 10–19% for the whole population and 23–33% for early flowering genotypes in the intermittent drought. Delay in flowering under intermittent drought condition at both locations was associated with yield reduction; genotypes that exhibited shorter delay in flowering had smaller yield reduction percentage and larger number of panicles. At Chum Phae, where grain yield reduction was associated with flowering time, genotypes with longer flowering duration under terminal drought had smaller yield reduction, and this was found even among genotypes that flowered about the same time under flood condition. However, there was no association between delay in flowering and flowering duration. It is concluded that delay in flowering appears promising as a selection criterion under intermittent drought conditions, provided a higher yield reduction can be achieved for example by using an increased irrigation interval.

1. Introduction

In the Mekong region, the majority of rice growing areas are classified as rainfed lowland ecosystem (OAE, 2003). Grain yield is low and varied across years and locations due to large environmental variability across the toposequence positions, soil types and seasonal rainfall patterns (Ouk et al., 2007; Kamoshita et al., 2008). The rainfed lowland rice crop is subjected to frequent drought especially late in the growing season, around October in north-east Thailand (late season terminal drought) but other types of drought, early season drought and intermittent drought are also common (Kamoshita et al., 2008; Fukai and Ouk, 2012). Different types of drought develop in rainfed rice fields, and characterization of the prevalent drought regimes for the region concerned is essential for identifying appropriate drought screening methods and also drought resistance traits that could be used for screening.

The success of a specific drought screening method is dependent on the discrimination of traits/genotypes reflecting that of the target environment. In order to make greater progress in selecting for drought resistant rice varieties, the use of managed environments in research stations was advocated by Lafitte et al. (2002). While the application of uniform, repeatable and controlled stress environment can be achieved more readily in the dry season and this may possibly maximize the genetic component of the observed variation, the extrapolation of results to natural target environments in the wet season can be difficult (Kamoshita et al., 2008). Phenotyping facilities for screening rice genotypes for drought resistance are increasingly available. While terminal drought is commonly used for drought screening in the Mekong region (Pantuwan et al., 1997; Fukai and Ouk, 2012), the drought stress level may be too severe to

* Corresponding author.
E-mail address: boonrat@brrd.mail.go.th (B. Jongdee).

http://dx.doi.org/10.1016/j.fcr.2015.02.003
0378-4290/

be representative of the drought that commonly develops during the wet season. Thus, intermittent drought screening methodology was suggested to target the moderately severe drought that is common during the wet season (Xangsayasane et al., 2014b). However, they found the drought stress level in the intermittent screening in the wet season was too low for discriminating genotypes for drought resistance, but by combining both wet and dry season screenings, genotypes identified as drought resistant were found to perform well in farmer's rainfed lowland fields in the wet season in Laos (Xangsayasane et al., 2014a).

While grain yield is commonly used as a selection criterion, determining grain yield accurately for a large number of genotypes can require a large input of resources, and indirect selection may be more efficient for a breeding program if we can identify a trait that can be determined with reduced resources but is highly heritable and is related to the genotypic variation in grain yield. Delay in flowering under drought stress has been found to be one of the traits associated with drought resistance in rice (Bernier et al., 2007) and it can be used for prediction of genotypic performance in drought-prone rainfed lowlands (Pantuwan et al., 2002b). While the delay in flowering under drought conditions appeared to be related to drought susceptibility, in experiments reported by Kumar et al. (2009), the results were confounded by the flowering time of genotypes, as shorter delays were found in early flowering genotypes which escaped from severe drought that developed late in the season. Commonly, delay in flowering is calculated as the difference in flowering time of genotype under stress condition and under flooded control (Pantuwan et al., 2002b; Sellamuthu et al., 2011; Xangsayasane et al., 2014b), and the flowering time is estimated on the whole plot basis. However, the delay in flowering may not be accurately estimated in this manner, as flowering time varies not only among plants but also within a plant depending on the number of tillers and panicles (Yoshida, 1981). The time interval for flowering of an entire panicle is normally four to seven days (Moldenhauer and Slaton, 2004). Within the same panicle it may take 7–10 days for all the spikelets to complete anthesis. Further, drought affects tillering pattern and subsequent panicle number (Sellamuthu et al., 2011; Kanjoo et al., 2012), and these may also affect flowering duration within a plot. Thus, the measurement of the duration of flowering (i.e. time taken from the first to the last flower) within a plot under flood and drought conditions may provide better understanding of the delay in flowering on the plot basis. The objective of the present work was to identify the importance of plant characters associated with drought resistance, particularly delay in flowering under intermittent and terminal drought conditions and its relationship to flowering duration under terminal drought conditions.

2. Materials and methods

2.1. Experimental sites and conditions

Two identical experiments were conducted at Chum Phae (CPA; latitude 16°32′2.6″N, 102°6′0″E) and Ubon Ratchathani (UBN; latitude 15°19′52.35″N, longitude 104°40′55.15″E) Rice Research Centers in Northeast Thailand, during the 2009 wet season. The soils at the experimental sites were sampled from 3 trial areas (flood, intermittent drought and terminal drought trials) but as the soil characteristics did not differ greatly among these areas only the mean is shown in Table 1. The soil texture was characterized as clay-loam and sand, at CPA and UBN, respectively.

To ensure the terminal drought trial was exposed to severe drought without interference of rainfall, the sowing date of all trials was delayed to 20 August at CPA and 15 August 2009 at UBN, and transplanting was done on 17 and 7 September at CPA and UBN, respectively. Transplanting was done using 1 seedling per hill, at hill spacing of 20 cm × 20 cm. The plot size was 1 m × 1 m (25 plants per plot) and harvest area was 0.6 × 0.6 m (3 plants × 3 plants).

Table 1
Soil pH, organic matter (OM), N, P and K availability, CEC, and soil texture at CPA and UBN.

	CPA	UBN
pH (1:1 H_2O)	5.2	4.8
Organic matter (%)	1.1	0.5
Total N (%)	0.1	0.0
Available P (ppm)	20.6	26.6
Extractable K (ppm)	202.4	32.4
CEC (c mol/kg)	10.7	2.0
Sand (%)	27.0	91.9
Silt (%)	40.6	6.6
Clay (%)	32.8	1.5
Texture class	Clay loam	Sand

2.2. Water condition trials

There were three water condition trials; flood, intermittent and terminal drought conditions. Under the flood condition the paddy was flooded with rainwater and irrigation to a height of 1–10 cm above the soil surface throughout the crop growth. Under the intermittent drought condition, surface irrigation was applied in the same manner as the flood condition until 53–54 days after sowing (DAS), and then water was drained out of the paddy. The paddy was irrigated at 63, 75, 87, 96 and 105 DAS at CPA, and at 62, 71, 77, 89, 98 and 107 DAS at UBN before the plants showed any visual symptom of drought stress such as leaf wilting or rolling. On the day of irrigation, the paddy was flooded in the morning for 5–6 h and drained out in the afternoon and this cycle was repeated until mid-grain filling.

Under the terminal drought condition the paddy was supplied with irrigation water in the same manner as in the flood condition until the flood water was drained out at 67 DAS at both locations, 13–14 days later than the intermittent drought condition, after which no further irrigation was applied.

2.3. Genotypes

Two types of genotypes were used in the experiments; one group consisted of 37 photoperiod insensitive genotypes selected in the previous dry season, while the other group consisted of 26 photoperiod sensitive genotypes based on RD6 as a parent and selected in the previous wet season. There were also 7 parents and varieties. The selection had been based on high grain yield and leaf water potential (LWP) under flood, aerobic and drought conditions. The former group included 5 double haploid lines derived from CT9993-5-10-1-M/IR62266-42-6-2, and 26 lines from Surin1 backcross with drought resistant donor (Surin1*3/IR68586-CA-143). The latter group included 7 lines from RD6 backcross with drought resistant donor (RD6*2/IR58821-23-B-1-2-1) and a number of lines extracted from crosses between RD6 and various local varieties (3 lines each from cross with Haew Jan and Hom Bang, 2 lines each from cross with Luang Ema, Kiew, Pong Aew1, and Daw Yoa, and 1 line each from cross with Hom Bai, Loa, Daw Noi, Hom Toong1, Kaao Kaew and Jaao Daeng), and 5 lines from cross between RD6 and selected line UBN95009-SRN-41-2-1-1).

2.4. Measurements

Days to flower (DTF) were estimated by visual observation from the number of days after sowing to the day 50% of plants flowered in each plot under flood, intermittent and terminal drought conditions. The flowering delay under intermittent and terminal drought