Field Crops Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Field Crops Research

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

On-farm multi-location evaluation of occurrence of drought types and rice genotypes selected from controlled- water on-station experiments in Northeast Thailand

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A R T I C L E I N F O

Keywords:
Water deficit
Intermittent stress
Terminal drought
Multi-location trials
Screening

A B S T R A C T

Rainfed lowland rice is the most common crop ecosystem in Northeast Thailand and varieties well adapted to drought-prone environments are required. On-farm multi-location experiments were conducted for 3 years to determine the drought type commonly developed, to identify genotype by environment interaction for rainfed lowland rice and to examine whether genotypic variation in these experiments was related to that in on-station controlled water- environment screening experiments conducted previously (Monkham et al., 2015). Among 32 on-farm experiments, 4 experienced continuous drought with no standing water during the whole growing season, and 3 of them all in high toposequence positions died before maturity. For the remaining experiments, both intermittent and terminal droughts were common, while some experiments developed early season drought and delayed transplanting but resulted in no apparent yield penalty. The first set of multi-location experiments consisted of 14 experiments in 6 provinces in Northeast Thailand across 2 years with 24 common genotypes. Mean grain yield of 13 environments that were harvested was 2300–3900 kg ha^{-1} and no severe drought developed at any environment. While main effect of genotype was not significant for grain yield, genotype by environment interaction was significant, and the results of clustering analysis identified 3 environmental groups and 3 genotype groups that explained the main source of the genotype by environment interaction. The genotypic variation obtained in the on-farm multi-location experiments in one environmental group of low yielding environments was correlated with that obtained under earlier intermittent drought selection experiments on-station. The results also indicate the usefulness of screening genotypes based on short delays in the intermittent drought conditions on-station.

A second set of multi-location experiments conducted throughout Northeast Thailand to test the performance of four genotypes selected from the first set of multi-location experiments confirmed that these genotypes outperformed the popular variety KDML105. The present study confirmed the usefulness of initial screening under intermittent drought conditions conducted on research stations followed by further on-farm selection. It is suggested that on-station selection experiments should target yield levels representative of on-farm yield levels.

1. Introduction

Rice crops in Northeast Thailand are commonly grown under rainfed lowland conditions without irrigation water. The rice crops are often subjected to drought, and depending on its timing of occurrence and nature, drought can be classified into three groups; early drought, intermittent drought and terminal drought (Kamoshita et al., 2008). These different types of drought can occur at any time during the plant growing cycle and there is large variation in soil water level during the growth within Northeast Thailand (Fukai et al., 1999; Bell and Seng, 2004). Therefore, experiments testing the adaptation of selected genotypes should be located throughout the region and repeated for at least two seasons to account for large genotype by environment interaction (Cooper and DeLacy, 1994). Severe drought does not always occur in Northeast Thailand, and hence genotypes with high yield potential are also required (Cooper et al., 1999; Jongdee et al., 2006). Understanding the target environment of the breeding program and the response of rice genotypes to different environments including favourable conditions are key factors contributing to higher efficiency of the breeding program.

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http://dx.doi.org/10.1016/j.fcr.2017.05.004
Received 15 June 2016; Received in revised form 5 May 2017; Accepted 7 May 2017
0378-4290/

Table 1
Soil pH, organic matter, total N, available P, extractable K and CEC at 0–20, and 20–40 cm depths determined at each location of Set 1 multi-location experiments (location code is location (noted in text), 1(set) and toposequence (low, high) position) in Northeast Thailand.

Location	Depth (cm)	pH (1:1 H_2O)	Organic Matter (%)	Total N (%)	Available P (mg/kg) (Bray II)	Extractable K (mg/kg) (NH_4OAC pH7)	CEC (c mol/kg)	Texture Class
UDT1 high	0–20	4.72	0.612	0.035	3.20	33.60	1.95	Loamy sand
	20–40	5.13	0.493	0.029	3.39	27.07	2.39	Loamy sand
UDT1 low	0–20	4.93	0.792	0.044	6.00	90.54	1.90	Loamy sand
	20–40	5.02	0.633	0.036	6.05	52.27	3.32	Loamy sand
RE1 high	0–20	4.91	0.471	0.028	10.06	39.20	1.87	Sand
	20–40	5.00	0.463	0.027	10.61	26.14	1.11	Sand
RE1 low	0–20	4.87	0.389	0.023	11.00	16.80	1.01	Sand
	20–40	5.44	0.331	0.021	10.10	10.27	1.12	Sand
MHS1	0–20	4.80	0.384	0.023	3.54	35.47	1.34	Sand
	20–40	4.85	0.353	0.022	4.61	48.54	1.23	Sand
CYP1	0–20	4.53	0.839	0.046	10.13	28.00	1.95	Sand
	20–40	4.64	0.817	0.045	10.86	18.67	1.96	Sand
NK1	0–20	4.79	0.526	0.030	24.95	28.94	2.59	Loamy sand
	20–40	4.72	0.264	0.017	16.51	14.95	3.04	Loamy sand
UBN1	0–20	4.62	0.677	0.038	12.73	16.80	1.78	Loamy sand
	20–40	4.79	0.642	0.036	12.33	14.00	1.80	Loamy sand

In drought-prone Northeast and North Thailand and Laos, a large genotype by environment interaction for grain yield is common for rainfed lowland rice, and proper identification of the drought environment is required for understanding of the nature of the interaction (Cooper 1995; Cooper et al., 1999). For rainfed lowland rice in SE Asia, several drought types have been identified. Chang et al. (1979) used three drought types, early, mild intermittent and late. Inthavong et al. (2011) followed a similar drought classification system for rainfed lowland rice in Laos and identified early, middle and late season drought from observations in the farmers' field using the lack of standing water as a criterion. Terminal drought is common in SE Asia, and the yield reduction depends on the time of standing water disappearance in relation to flowering time (Jearakongman et al., 1995). Thus, the severity of terminal drought may be expressed as the number of days before or after flowering when standing water disappears from the field (Tsubo et al., 2006). A feature of the rainfed lowlands in SE Asia is large variation in water availability among the rice fields along a gentle slope of the topography (toposequence), and fields in high toposequence position often have shorter duration of standing water (Tsubo et al., 2006; Inthavong et al., 2012), but its implication on genotypic requirement is not clear (Xangsayasane et al., 2014a,b).

In the breeding program aimed for improving drought tolerance, genotypes may be selected under managed drought conditions (Blum, 1983; Richards, 2006; Kumar et al., 2008). Furthermore, under these controlled conditions, putative drought tolerance traits may be identified and used as selection criteria (Cooper, 1995; Richards, 1996; Jongdee et al., 2002; Jongdee et al., 2006). From their studies, several traits have been found to be associated with drought tolerance. For the genotypes used in the experiment reported by Monkham et al. (2015), selection was based on LWP, delay in flowering and the low yield reduction, and 3 genotype groups were developed from the selection; 1) good performance under flood, intermittent and terminal drought conditions, 2) good performance under flood and intermittent conditions and 3) good performance under flood and terminal drought conditions.

Using these genotypes selected from the earlier work of Monkham et al. (2015), multi-location experiments were conducted on-farm across locations in Northeast Thailand in 3 years. An objective of the 32 experiments was to identify the occurrence of drought types in the region, within which appropriateness of managed drought screening, particularly of the intermittent screening method was evaluated. Objectives of the first set of multi-location experiments conducted in the first two years were to identify the nature of genotype by environment interaction in Northeast Thailand, and to determine the appropriateness of the genotypes selected and traits identified to contribute to higher yield under different types of drought screening methods on research station (as described in Monkham et al., 2015) for their performance on farmers' fields at different locations of the target breeding domain. The second set of multi-location experiments conducted in the third year using four promising genotypes selected from the first set of multi-location experiments was to confirm the performance of these selected lines in widely scattered areas in the target environment of Northeast Thailand.

2. Materials and methods

2.1. Experiment locations

The first set of multi-location experiments (Set 1) was conducted in farmer's fields in Northeast Thailand; 8 locations in wet season 2010 and 6 locations in wet season 2011.

In 2010, the experiments consisted of Udon Thani (UDT high and low position), Roi Et (RE high and low position), Maha Sarakam (MHS), Chaiyaphum (CYP), Nong Khai (NK), and Ubon Ratchathani (UBN) provinces. In 2011, the same locations were used except Nong Khai and Ubon Ratchathani. Each experiment (location/year/toposequence position) was considered an environment and employed an alpha lattice design with three replications. Soil characteristics at the different locations are shown in Table 1.

In 2015, another set of multi-location experiments (Set 2) was conducted to test the performance of 4 genotypes selected from the multi-location experiments conducted in 2010 and 2011 (Set 1). The experiments in 2015 were conducted at 18 locations (environments) with high and low toposequence field levels which were scattered throughout Northeast Thailand; Maha Sarakham (MHS), Nakhon Ratchasima (NKS), Surin (SRN), Sakon Nakhon (SKN), Bueng Kan (BK), Ubon Ratchathani (UBN), Amnat Charoen (ANC), and Nong Bua Lam Phu (NBL). Each experiment in 2015 utilised a randomized complete block design with three replications.

2.2. Genotypes

Genotypes for the first set of multi-location experiments were selected based on grain yield from three water conditions reported by Monkham et al. (2015). Four groups of genotypes used were 1) high yielding in all conditions, 2) high yielding in intermittent drought and flood, 3) high yielding in terminal drought and flood conditions and 4)