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EVALUATION OF RICE GERMPLASM FOR YIELD TRAITS AND AMYLOSE CONTENT UNDER DROUGHT STRESS

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SUMMARY

A set of 44 rice cultivars were evaluated for yield traits and amylose content under controlled reproductive stage drought. Drought tolerance indices viz., leaf rolling, leaf drying, and levels of drought tolerance were measured. A total of 38 cultivars had scores of 0–3 for leaf rolling. Forty cultivars showed scores of 0–2 for leaf drying. Twenty cultivars showed drought tolerance scores of 0–3. Six cultivars, namely, IR75499-73-1-B, V3M-92-1, IR75499-21-1-B, V3M-109-2, IR78997-B-16-B-B-B-SB2, and IR78948-B-21-B-B-B, could be selected for drought tolerance, leaf rolling, and leaf drying with drought scores of 0–1. These cultivars were expected to provide higher yield components. The range of yield decline was 10.61–26.06 g/cluster under water stress. Four cultivars showed combined drought tolerance, high yield, and good quality under reproductive-stage drought stress. The drought-tolerant cultivars (V3M-92-1, IR78997-B-16-B-B-B-SB2, IR75499-73-1-B, and IR78948-B-21-B-B-B) identified in this study could be further deployed in rice breeding programs.

Keywords: Drought tolerance, screening, high yield, amylose content

Key findings: Four cultivars were identified for drought tolerance, high yield, and low amylose content under reproductive-stage drought stress. This study will provide information on the yield, yield component traits, and amylose content of 44 rice cultivars under drought conditions, which could be useful in rice breeding programs.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of over three billion people in the world. Asia, where a majority of rice is grown, accounts for approximately 90% of the world's consumption of rice. There are many different ecologies for rice cultivation ranging from irrigation to upland, submerged to flooded areas, to deep water. Climate change has become more complex in recent years, and droughts have become more severe, leading to a shortage of farming water (Wassmann *et al*., 2009). The intensity and frequency of droughts are expected to worsen (Bates *et al*., 2008). The reproductive stage of rice is highly susceptible to drought stress because the pollination of rice flowers is sensitive to water stress (O Toole 1982; Venuprasad *et al*., 2007).

Drought is one of the major abiotic stresses that limit rice production and stable productivity (Lanceras *et al*., 2004). Improved resilience to drought during flower development is an important goal for contributing to increased rice yield production under drought stress (Richards *et al*., 2010). This scenario has been in place for a long time, and efforts have been made to understand the mechanisms involved in drought tolerance and the development of drought-tolerant cultivars in rice. In the past, rice breeding for drought tolerance mainly focused on secondary characteristics, such as root architecture and water efficiency (Babu *et al*., 2003; Lanceras *et al*., 2004). Earlier, it has also been believed that grain yield is an unsuitable selection criterion in breeding rice for drought tolerance. This unsuitability has been attributed to the high complexity of the genetic control of drought, which leads to its low heritability under drought. Several experiments to standardize the procedures for the uniform screening of segregating populations for grain yield under reproductive-stage drought (Venuprasad *et al*., 2007, 2008; Kumar *et al*., 2008, 2009) showed the moderate heritability of grain yield under drought, thereby confirming the suitability of grain yield as a selection criterion. It was also reported that, in large mapping populations, the correlation between high yield potential and good yield under drought is low but always positive (Kumar *et al*., 2008), suggesting the possibility of combining high yield potential and good yield under drought successfully.

For developing a new variety, breeders focus not only on a single trait but also on combining all desirable characteristics. In addition to yield and other agronomic traits, resistance traits and/or grain quality traits are also very important. Besides yield, rice quality is also affected by limited water availability (Pandey *et al*., 2014). Usually, there are many varieties of rice—those with high yield and drought tolerance—but very few are high yielding, resistant to drought, and possess good quality. Suitable rice cultivars with a combination of good quality, pest resistance, short duration, and traits related to yield are often difficult to find. Part of the improvement in the cooking and eating quality of rice comes from improved amylose content (AC). The AC is one of the main factors that affect the cooking and eating quality of rice grains (Fitzgerald *et al*., 2008). Wide adaptation, high productivity, and improved quality have been the standards for breeders, and the identification of donors to be used as parents is also the most important step in breeding programs and developing populations for genetic analysis (Atlin, 2003). No selection method can extract a good cultivar if the parents used in the program are unsuitable. While there are many evaluation criteria for selecting the optimal rice variety, in this study, an attempt was made to select rice varieties based on yield criteria. Thus, the present study was undertaken with the objective of evaluating rice cultivars for drought tolerance based on the phenotype variation of yield component traits and AC analysis under controlled drought stress.

MATERIALS AND METHODS

Plant material

The 44 rice cultivars used in this study were collected by the Cuu Long Delta Rice Research Institute (CLRRI) and International Rice Research Institute (IRRI). A list of the cultivars characterized under drought is presented in Table 1.

Screening for drought tolerance

The donor screening experiment for reproductive-stage drought stress in the dry season was laid out in a randomized complete block design with three replications at the greenhouse and field at the High Agricultural Technology Research Institute for Mekong Delta, Vietnam. In this study, 44 rice cultivars were evaluated for leaf rolling score, dried leaf levels, and drought score to screen for drought tolerance at vegetative stage (40 days) in accordance with the standard evaluation system (IRRI, 1996) (Tables 2, 3 and 4). The seeds of these cultivars were soaked, germinated in an incubator, and sown in plastic trays. After 15 days, they were transplanted into cement pots with dimensions of 15 cm × 20.

At 10 days after transplanting, drainage through drain taps was set up, and water was not provided until flowering. The following fertilizers were applied basally during the dry season: 100 kg of N, 40 kg of P_2O_5, and 30 kg of K_2O. Subsequently, samples were obtained to analyze agronomic characters and grain yield, contributing plant height, tillers per plant, filled grains per panicle, 1000-grain weight, and yield/cluster.

Evaluation of AC

AC was estimated using the procedure of Sadavisamvà Manikampls (1992). A rice flour sample weighing approximately 100 mg was extracted overnight in a solution of 1 ml of absolute ethanol and 10 ml of 1 N NaOH. This suspension was heated in a boiling water bath for 10 min and then cooled to room temperature. Samples were diluted to 100 ml with distilled water. A 2.5 ml sample suspension was added to 20 ml of distilled water in a 100 ml flask, and 1 ml of 1 M acetic acid was added to acidify the sample along with 1 ml of 0.2% I_2 in 2% KI. Distilled water was added to a volume of 100 ml. The suspension was mixed well and then kept for 15 min. A control solution was prepared by replacing the sample suspension with 5 ml of 0.09 M NaOH solution. This control solution was used for calibration to 0 at 590 nm with a spectrophotometer. Samples with known high, medium, and low AC values were used to draw the standard amylose curve.

Table 1. List of 44 rice germplasm used in this study.

No.	Rice germplasm	Origin	No.	Rice germplasm	Origin
1	OM4900	CLRRI	23	V3M-109-2	IRRI
2	OM 1490	CLRRI	24	WAB272-B-B-8-H1	IRRI
3	AS 996	CLRRI	25	WAB340-B-B-2-H2	IRRI
4	M362	IRRI	26	WAB176-42-HB	IRRI
5	BASMATI	IRRI	27	IR78937-B-20-B-B-1	IRRI
6	Basmati DB	CLRRI	28	WAB880-1-38-18-20-P_1-HB	IRRI
7	OM6162	CLRRI	29	WAB881SG9	IRRI
8	Swarna Sub1	IRRI	30	IR78997-B-16-B-B-B-SB2	IRRI
9	IR 64Sub1	IRRI	31	IR78966-B-10-B-B-B-SB1	IRRI
10	IRGA318-11-6-9-2B	IRRI	32	IR78944-B-8-B-B-B	IRRI
11	IR78966-B-10-B-B-B-2	IRRI	33	IR78941-B-16-B-B-B	IRRI
12	IR78913-B-10-B-B-B	IRRI	34	IR78948-B-21-B-B-B	IRRI
13	IR75499-73-1-B	IRRI	35	IR78942-B-2-B-B-2	IRRI
14	IR78913-B-19-B-B-B	IRRI	36	IR78937-B-20-B-B-3	IRRI
15	AZUCENA	IRRI	37	IR78985-B-13-B-B-B	IRRI
16	IR78933-B-24-B-B-2	IRRI	38	IR78933-B-24-B-B-1	IRRI
17	IR78933-B-24-B-B-3	IRRI	39	WABC165	IRRI
18	IR78933-B-24-B-B-4	IRRI	40	IR80315-49-B-B-4-B-B-B	IRRI
19	IR79008-B-11-B-B-1	IRRI	41	IR78966-B-16-B-B-B	IRRI
20	IR75499-38-1-B	IRRI	42	IR78913-B-22-B-B-B	IRRI
21	V3M-92-1	IRRI	43	OMCS2000	CLRRI
22	IR75499-21-1-B	IRRI	44	IR78939-B-9-B-B-B	IRRI

CLRRI: Cuu Long Delta Rice Research Institute; IRRI: International Rice Research Institute

Table 2. Leaf rolling level at vegetative stage for each entry following a 0–9 scale of the standard evaluation system (IRRI 1996).

Scale	Description
0	Leaves healthy
1	Leaves starting to fold
3	Leaves folded (deep V-shaped)
5	Leaves fully cupped (U-shaped)
7	Leaf margins touching (O-shaped)
9	Leaves tightly rolled

Table 3. Drought tolerance scores at the vegetative stage for each entry following the scales of the standard evaluation system (IRRI 1996).

Scale	Description	Rate
1	No symptoms	Highly resistant
3	Slight tip drying	Resistant
5	Tip drying extended to ¼ length in most leaves	Moderately resistant
7	¼ to ½ of the leaves fully dried	Moderately susceptible
9	All plants apparently dead	Highly susceptible

Table 4. Leaf drying level in vegetative stage for each entry following the 0–9 scale of the standard evaluation system (IRRI 1996).

Scale	Description	Rate
0	No symptoms	Highly resistant
1	Slight tip drying	Resistant
3	Tip drying extended up to 1/4 length in most leaves	Moderately resistant
5	One-fourth to 1/2 of all leaves dried	Moderately susceptible
7	More than 2/3 of all leaves fully dried	Susceptible
9	All plants apparently dead	Highly susceptible

AC was used to classify milled rice into waxy (1%–2% amylose), very low AC (2%–9% amylose), low AC (10%–20% amylose), intermediate AC (20%–25% amylose), and high AC (25%–33% amylose) rice.

Statistical analysis

One-way analysis of variance (ANOVA) appropriate for the specified experimental and treatment design was performed on each measured trait listed in this study by using SAS 9.4. Data were compared through ANOVA followed by Duncan multiple range tests when significant differences were found at 5%.

RESULTS AND DISCUSSION

Screening for the drought tolerance of rice germplasm at the seedling stage based on phenotype

Before the initiation of any breeding program or mapping experiments, drought-tolerant donors are identified through germplasm screening. These donors could be used either directly for testing and release in the target environment or as parents for further backcrossing programs to develop breeding lines for target traits. Moreover, the impact of drought stress on different physiological changes among rice germplasm becomes considerably more significant and emphasizes the importance of screening rice germplasm for drought tolerance (Kumar *et al*., 2015). Drought tolerance was evaluated through screening at the vegetative stage based on the levels of leaf rolling, dried leaf levels, and drought tolerance levels (Table 5). The observations for LR were observed by using a 0–9 scale. Almost all of the cultivars from IRRI had scores of 0–3. Specifically, 12 cultivars had a score of 0 and 13 had scores of 1 and 3 for leaf rolling level. Cultivars IR78937-B-20-B-B-1and IR79008-B-11-B-B-1 had a score of 5. The susceptibility or tolerance to drought was identified through the variation in the dried leaf levels of IRRI cultivars with the scores of 0–2.

In rice, leaf rolling and tip drying under drought stress are some of the best criteria for estimating the levels of drought tolerance through large-scale screening (Pandey and Shukla, 2015). In this study, rice cultivars were evaluated using leaf rolling, drought tolerance, and leaf drying scores to screen for drought tolerance. Leaf rolling is one of the common elements selected to determine water shortage in rice.

Table 5. Evaluation of traits related to the drought tolerance of 44 rice germplasm at the seedling stage.

No.	Rice germplasm	Scale			No.	Rice germplasm	Scale		
		LR	LD	DT			LR	LD	DT
1	OM4900	3	1	3	23	V3M-109-2	0	0	1
2	OM 1490	9	4	7	24	WAB272-B-B-8-H1	0	0	3
3	AS 996	1	2	5	25	WAB340-B-B-2-H2	1	1	3
4	M362	0	0	5	26	WAB176-42-HB	1	1	3
5	BASMATI	1	2	7	27	IR78937-B-20-B-B-1	5	2	7
6	Basmati ĐB	3	2	5	28	WAB880-1-38-18-20-P_1-HB	1	2	0
7	OM6162	3	2	3	29	WAB881SG9	1	1	3
8	Swarna Sub1	9	5	9	30	IR78997-B-16-B-B-B-SB2	0	0	1
9	IR 64Sub1	5	5	7	31	IR78966-B-10-B-B-B-SB1	0	1	3
10	IRGA318-11-6-9-2B	3	2	7	32	IR78944-B-8-B-B-B	3	2	5
11	IR78966-B-10-B-B-B-2	1	1	3	33	IR78941-B-16-B-B-B	3	2	3
12	IR78913-B-10-B-B-B	3	2	5	34	IR78948-B-21-B-B-B	1	1	1
13	IR75499-73-1-B	0	0	0	35	IR78942-B-2-B-B-2	1	2	5
14	IR78913-B-19-B-B-B	3	2	5	36	IR78937-B-20-B-B-3	1	2	7
15	AZUCENA	3	1	5	37	IR78985-B-13-B-B-B	1	2	7
16	IR78933-B-24-B-B-2	0	1	5	38	IR78933-B-24-B-B-1	3	2	7
17	IR78933-B-24-B-B-3	1	1	5	39	WABC165	3	2	5
18	IR78933-B-24-B-B-4	0	0	3	40	IR80315-49-B-B-4-B-B-B	3	2	7
19	IR79008-B-11-B-B-1	5	2	3	41	IR78966-B-16-B-B-B	0	1	3
20	IR75499-38-1-B	0	0	5	42	IR78913-B-22-B-B-B	1	2	3
21	V3M-92-1	0	0	1	43	OMCS2000	9	4	5
22	IR75499-21-1-B	0	0	1	44	IR78939-B-9-B-B-B	3	2	5

LR: leaf rolling; LD: Leaf drying; DT: drought tolerant

The variation in leaf rolling in this study ranged from 0 to 9, indicating that leaf rolling was a good trait for evaluating drought tolerance in this germplasm. Drought scoring was also used as a primary criterion in the screening of rice genotypes for drought tolerance (IRRI, 2014). The evaluation of drought tolerance levels (Table 1) showed that seven rice cultivars could be used to achieve the goal of breeding for drought tolerance. These cultivars were IR75499-73-1-B, V3M-92-1, IR75499-21-1-B, V3M-109-2, IR78997-B-16-B-B-B-SB2, IR78948-B-21-B-B-B, and WAB880-1-38-18-20-P1-H with drought scores of 0–1. In this study, the significant variations in the drought scores of these rice cultivars indicated the usefulness of this trait in screening for drought tolerance. However, stress due to drought, particularly drought stress during the flowering stage, remains the biggest challenge (Buu and Lang, 2017).

Selection for grain yield under drought at the reproductive stage

Variations in agronomic traits are important for crop breeding, both for selecting parents to generate segregating populations and selecting superior genotypes in segregating populations. The selection and breeding of drought-tolerant genotypes are especially difficult (Tirado and Cotter, 2010). Therefore, it is essential to perform intense drought screening, which intelligibly differentiates drought-susceptible genotypes from drought-tolerant genotypes, for the selection of rice genotypes under drought stress (Swamy *et al*., 2012). The morphological characteristics of the 44 rice cultivars under drought conditions are shown in Table 6. The plant height of these cultivars varied widely and ranged from 85 cm to 140 cm. The total tillers ranged from 5 tillers/plant to 18 tillers/plant. The IR75499-73-1-B cultivar had the highest tillering ability among the tested cultivars (18 tillers/plant). Filled grain showed great variation among cultivars. The cultivars with the highest filled grain in these cultivars were IR78913-B-22-B-B-B (213) and OM4900 (210.5).

In this study, the varieties with good agronomic traits were identified for further use in rice breeding programs. The plant height of most of these cultivars was low–medium (85–120 cm). According to Yoshida (1981), moderate plant height is more favorable in locations where it is difficult to control water and resistance to lodging. The 1000-grain weight of seeds is a useful tool for calculating seeding and yield rates (Anonymous, 2007). The variation in the 1000-grain weight of the 44 cultivars was not large. The cultivars with the highest 1000-grain weight were OM6162, IR78913-B-19-B-B-B, WABC165, WAB272-B-B-8-H1, IRGA318-11-6-9-2B, and BASMATI (>28 g). The grain yield per cluster of these cultivars varied widely and ranged from 12.12 g/cluster to 26.6 g/cluster. The highest grain yield per cluster was recorded by IR75499-73-1-B (26.06 g/cluster), followed by IR78997-B-16-B-B-B-SB2 (24.85 g/cluster) IR78913-B-22-B-B-B (22.73 g/cluster), WAB881SG9 (22.42 g/cluster), IR78985-B-13-B-B-BO, OM4900, and V3M-92-1 (21.82 g/cluster). In this study, the cultivars were grouped into the two ranges of 23.4–26.9 and 27.1–28.6 g on the basis of the obtained milled grain weights. After evaluating 44 cultivars under field conditions, seven rice cultivars, namely, IR75499-73-1-B, IR78997-B-16-B-B-B-SB2, IR78913-B-22-B-B-B, WAB881SG9, IR78985-B-13-B-B-BO, OM4900, and V3M-92-1, were identified as breeding materials for breeding programs. This study reported on the progress achieved in evaluating drought-tolerant cultivars based on rice germplasm through selection for grain yield under drought.

Variation in the AC of 44 rice germplasm

In addition to rice yield, the quality of rice is affected by limited water availability. AC is one of the main factors that affect the cooking and eating quality of rice grains (Fitzgerald *et al*., 2008). AC is considered as a rice quality trait that is critical to softness and vice versa (Lang, 2002). Cooking quality is determined primarily by the AC. The results in Table 7 showed t8 cultivars with low AC < 20%, including IR78933-B-24-B-B-2 (12.0%), IR78948-B-21-B-B-B (16.2%), WAB272-B-B-8-H1 (16.4%), OM6162 and V3M-92-1 (18.3 %), IR78913-B-19-B-B-B (18.7%), IR75499-73-1-B (18.9%), and OM4900 (19.8%). These cultivars could constitute important genetic resources for improving the cooking properties of rice in several rice breeding programs. In present study, three rice cultivars (IR75499-73-1-B, V3M-92-1, and OM4900) had different yield/cluster groups and low AC. These results showed that some elite cultivars/lines can be deployed for breeding programs combining yield and quality under drought.

Table 6. Grain yield of 44 rice germplasm under reproductive-stage drought.

No.	Name of cultivar	Plant height (cm)	Tillers	Full grain/ panicle	1000-grain weight (g)	Yield (g/ cluster)
1	OM4900	100g	15cd	210.5a	26.6c-h	21.82b-e
2	OM1490	85j	15cd	123op	26.3d-h	12.42jk
3	AS 996	85j	14d	147ijk	27.5a-f	15.76g-j
4	M362	106e	6j	142kl	26.6c-h	16.97f-i
5	BASMATI	120b	10fg	156gh	28.2abc	14.55h-j
6	Basmati ĐB	100g	12e	147ijk	27.3a-g	15.76g-j
7	OM6162	95h	10fg	128no	28.6a	20.30c-f
8	Swarna Sub1	114c	14d	156gh	26.4d-h	12.73jk
9	IR64Sub1	105ef	12e	148ijk	26.5d-h	18.79d-g
10	IRGA318-11-6-9-2B	110d	11ef	187c	28.4ab	17.88e-h
11	IR78966-B-10-B-B-B-2	105ef	14d	146ijk	26.7c-h	19.09c-g
12	IR78913-B-10-B-B-B	105ef	12e	175d	27.4a-g	17.88e-h
13	IR75499-73-1-B	100g	18a	201b	27.2a-g	26.06a
14	IR78913-B-19-B-B-B	120b	8hi	145jk	28.4ab	12.42jk
15	AZUCENA	102fg	11ef	187c	26.3d-h	20.61c-f
16	IR78933-B-24-B-B-2	140a	12e	166ef	25.9f-i	12.12jk
17	IR78933-B-24-B-B-3	100g	16bc	175d	26.7c-h	12.73jk
18	IR78933-B-24-B-B-4	105ef	10fg	184c	26.5d-h	12.73jk
19	WAB326-B-B-7-H1	100g	11ef	148ijk	26.7c-h	15.76g-j
20	IR79008-B-11-B-B-1	85j	10fg	160fg	25.4hi	20.30c-f
21	IR75499-38-1-B	90i	11ef	142kl	26.8b-h	20.61c-f
22	V3M-92-1	90i	10fg	136lm	27.4a-g	21.82b-d
23	IR75499-21-1-B	86j	11ef	159g	27.9a-d	19.70c-f
24	V3M-109-2	104ef	11ef	111r	26.5d-h	15.76g-j
25	WAB272-B-B-8-H1	140a	17ab	174d	28.4ab	12.42jk
26	WAB340-B-B-2-H2	140a	12e	123op	26.9b-h	12.73jk
27	WAB176-42-HB	140a	12e	120pq	27.8a-e	13.94i-k
28	IR78937-B-20-B-B-1	100g	9gh	114qr	24.3ij	10.61k
29	WAB880-1-38-18-20-P_1-HB	85j	8hi	132mn	27.9a-d	20.00c-f
30	WAB881SG9	99g	5k	169de	24.3ij	22.42a-d
31	IR78997-B-16-B-B-B-SB2	112cd	10fg	104s	27.6a-e	24.85ab
32	IR78966-B-10-B-B-B-SB1	90i	12e	112r	25.8ghi	14.85h-j
33	IR78944-B-8-B-B-B	105ef	15cd	114qr	27.1a-g	12.73jk
34	IR78941-B-16-B-B-B	110d	14d	100s	23.4j	15.45g-j
35	IR78948-B-21-B-B-B	105ef	12e	104s	25.4hi	12.42jk
36	IR78942-B-2-B-B-2	105ef	15cd	123op	26.2e-h	12.12jk
37	IR78937-B-20-B-B-3	90i	12e	145jk	26.4d-h	12.73jk
38	IR78985-B-13-B-B-B	85j	15cd	162fg	27.8a-d	21.82b-d
39	IR78933-B-24-B-B-1	95h	14d	174d	23.5j	15.76g-j
40	WABC165	100g	16bc	156gh	28.4ab	18.79d-g
41	IR80315-49-B-B-4-B-B-B	95h	15cd	174d	23.4j	17.27f-i
42	IR78966-B-16-B-B-B	100g	7ij	150hij	23.5j	18.79d-g
43	IR78913-B-22-B-B-B	95h	15cd	213a	26.5d-h	22.73a-c
44	OMCS 2000	90i	14d	187c	26.5d-h	18.79d-g
	CV%	1.57	6.96	2.02	3.08	13.83
	$LSD_{0.05}$	0.67	0.36	1.31	0.35	1.25

Table 7. Evaluation of AC of 44 rice germplasm.

No.	Name of cultivar	AC (%)	No.	Name of cultivar	AC (%)
1	OM4900	19.8j-m	23	IR75499-21-1-B	21.2hij
2	OM1490	24.3cd	24	V3M-109-2	23.6c-f
3	AS 996	24.5c	25	WAB272-B-B-8-H1	16.4n
4	M362	24.1cd	26	WAB340-B-B-2-H2	24.5c
5	BASMATI	22.6d-g	27	WAB176-42-HB	27.3a
6	Basmati DB	24.3cd	28	IR78937-B-20-B-B-1	26.3ab
7	OM6162	18.3m	29	WAB880-1-38-18-20-P_1-HB	24.2cd
8	Swarna Sub1	24.3cd	30	WAB881SG9	24.1cd
9	IR64Sub1	23.5c-f	31	IR78997-B-16-B-B-B-SB2	23.5c-f
10	IRGA318-11-6-9-2B	24.2cd	32	IR78966-B-10-B-B-B-SB1	24.1cd
11	IR78966-B-10-B-B-B-2	21.0hij	33	IR78944-B-8-B-B-B	25.0bc
12	IR78913-B-10-B-B-B	20.1jkl	34	IR78941-B-16-B-B-B	24.5c
13	IR75499-73-1-B	18.9klm	35	IR78948-B-21-B-B-B	16.2n
14	IR78913-B-19-B-B-B	18.7lm	36	IR78942-B-2-B-B-2	24.0c-e
15	AZUCENA	24.5c	37	IR78937-B-20-B-B-3	23.4c-f
16	IR78933-B-24-B-B-2	12.0o	38	IR78985-B-13-B-B-B	23.5c-f
17	IR78933-B-24-B-B-3	24.0cde	39	IR78933-B-24-B-B-1	24.5c
18	IR78933-B-24-B-B-4	24.5c	40	WABC165	21.1hij
19	WAB326-B-B-7-H1	24.3cd	41	IR80315-49-B-B-4-B-B-B	24.7bc
20	IR79008-B-11-B-B-1	24.2cd	42	IR78966-B-16-B-B-B	23.5c-f
21	IR75499-38-1-B	20.5ijk	43	IR78913-B-22-B-B-B	22.1ghi
22	V3M-92-1	18.3m	44	OMCS 2000	24.1cd
	CV%			3.72	
	$LSD_{0.05}$			0.36	

Means within columns with the same letter showed no significant difference at 0.05.

CONCLUSION

Four cultivars with combined drought tolerance, high yield, and low AC under reproductive-stage drought stress were identified: V3M-92-1, IR78997-B-16-B-B-B-SB2, IR75499-73-1-B, and IR78948-B-21-B-B-B. This study will provide information on the yield, yield component traits, and AC of rice germplasm under drought, which may be useful in rice breeding programs.

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REFERENCES

Anonymous (2007). Albert Agriculture and Food; Using 1,000 Kernel Weight for Calculating Seeding Rate and Harvest Losses.

Atlin G (2003). Improving drought tolerance by selecting for yield. In: Breeding Rice for Drought-Prone Environments, eds K. S. Fischer, R. Rice breeding strategies for north east Thailand. I. Genotypic variation and genotype-environment interactions for grain yield. *Field Crops Res*. 64: 131-151.

Babu RC, Nguyen BD, Chamarerk V, *et al* (2003). Genetic analysis of drought resistance in rice by molecular markers: association between secondary traits and field performance. *Crop Sci*. 43: 1457-1469.

Bates BC, Kundzewicz ZW, Wu S, Palutikof JP (2008). Climate change and water. IPCC Technical Paper VI, Geneva, pp. 210.

Buu BC, Lang NT (2017). New rice varieties adapted to climate change in the Mekong River Delta of Vietnam. *Vietnam J. Sci. Technol. Eng*. 60(2): 30-33.

Fitzgerald MA, McCouch SR, Hall RD (2008). Not just a grain of rice: The quest for quality. *Trends Plant Sci*. 14(3): 133-139.

IRRI (1996). Standard evaluation system for rice. The International Rice Research Institute, Manila, the Philippines.

IRRI (2014). Standard evaluation system for rice. 5th Ed. International Rice Research Institute (IRRI), Los Banos, Philippines.

Kumar A, Bernier J, Verulkar S, Lafitte RH, Atlin GN (2008). Breeding for drought tolerance: Direct selection for yield, response to selection and use of drought-tolerant donors in upland and lowland-adapted populations. *Field Crops Res*. 107: 221-231.

Kumar A, Verulkar SB, Dixit S, Chauhan B, Bernier J, Venuprasad R, Zhao D, Shrivastava MN (2009). Yield and yield-attributing traits of rice (*Oryza sativa* L.) under lowland drought and suitability of early vigor as a selection criterion. *Field Crops Res*. 114: 99-107.

Kumar R, Sreenu K, Singh N, Jain N, Singh NK, Rai V (2015). Effect of drought stress on contrasting cultivars of rice. *Int. J. Trop. Agric*. 33(2): 1559-1564.

Lanceras JC, Pantuwan G, Jongdee B, Toojinda T (2004). Quantitative trait loci associated with drought tolerance at reproductive stage in rice. *Plant Physiol*. 135: 384-399.

Lang NT (2002). Protocol for basics of biotechnology, Agri. Pub. House. Ho Chi Minh, Vietnam.

O'Toole JC (1982). Adaptation of rice to drought prone environments. In: Drought resistance in crops with emphasis on rice . IRRI, Los Baños, Philippines, pp. 195-213.

Pandey A, Kumar A, Pandey DS,Thongbam PD (2014). Rice quality under water stress. *Indian J. Adv. in Plant Res.* 1(2): 23-26.

Pandey V, Shukla A (2015). Acclimation and tolerance strategies of rice under drought stress. *Rice Sci*. 22: 147-161.

Richards RA, Rebetzke GJ, Watt M, Condon AG, Spielmeyer W, Dolferus R (2010). Breeding for improved water productivity in temperate cereals: phenotyping, quantitative trait loci, markers and the selection environment. *Funct. Plant Biol*. 37: 85-97.

Sadavisam, Manikam (1992). Biochemical method for agricultural sciences Wiley eastern, New Delhi, India.

Swamy BPM, Kumar A (2012). Sustainable rice yield in water-short drought-prone environments: Conventional and molecular approaches. In: Lee T S. Irrigation Systems and Practices in Challenging Environments. German: In-Tech.

Tirado R, Cotter J (2010). Ecological farming: Drought-resistant agriculture. In: Erwood S, Truchi N, Stabinsky D. Greenpeace Research Laboratories Technical Note. Amsterdam, Netherland: the Netherlands Greenpeace International.

Venuprasad R, Lafitte HR, Atlin GN (2007). Response to direct selection for grain yield under drought stress in rice. *Crop Sci*. 47: 285-293.

Venuprasad R, Sta Cruz MT, Amante M, Magbanua R, Kumar A, Atlin GN (2008). Response to two cycles of divergent selection for grain yield under drought stress in four rice breeding populations. *Field Crops Res*. 107, 232-244.

Wassmann R, Jagadish SVK, Sumfleth K, Pathak H, Howell G, Ismail A, Serraj R, Redona E, Singh RK, Heuer S (2009). Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. *Adv. Agron*. 102: 91-133.

Yoshida, S (1981). Fundamentals of rice crop science. IRRI, Los Banos, Philippines.

Yue B, Xue W, Xiong L, Yu X, Luo L, Cui K, Jin D, Xing Y, Zhang Q (2006). Genetic basis of drought resistance at reproductive stage in rice: separation of drought tolerance from drought avoidance. *Genet*. 172: 1213-1228.