Journal of Agricultural Science and Technology A and B
& Hue University Journal of Science 7 (2017) 1-9
doi: 10.17265/2161-6256/2017.10.001S

Evaluation of Agronomic Characteristics, Drought Tolerance and Yield of Some Rice Varieties in Central Vietnam

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Abstract: The aim of the study was to evaluate the drought tolerance, agro-morphological characteristics and yield of 10 rice varieties collected from different locations. In experiment one, drought tolerance of rice varieties under artificial drought condition in the greenhouse was assessed through root and leaf characteristics. In experiment two, the growth and yield of rice varieties in the rainfed rice field was estimated. The results showed that drought has affected the root characteristics, leaf rolling and leaf drying of these varieties. In rainfed rice field of Thua Thien Hue and Quang Nam province, summer-autumn 2016 and winter-spring 2016-2017 crop season, these rice varieties grew and developed well. The growth time was 90-119 d in summer-autumn crop season, while in winter-spring crop season was 107-131 d. The yield of these rice varieties ranged from 37.02 quintals/ha to 56.33 quintals/ha and from 42.33 quintals/ha to 66.60 quintals/ha, respectively. Some rice varieties with high yields in both two crop seasons were OM4900, GSR38, IR93340 and OM7347. It is sugessted to conduct production experiment on a large area in rainfed field for these four varieties to evaluate them objectively and early put them into structure of rice varieties in Central Vietnam.

Key words: Central Vietnam, drought tolerance, growth, rice, variety, yield.

1. Introduction

In the world, there are 154 million ha of rice land and more than 45% of the land area dependent on rain water is severely affected by droughts [1]. The rice land area dependent on rain water is about 41 million ha, of which 95% is in Asia [2]. Drought is the most important factor affecting world food security, which can reduce over 50% of the average yield of some major food crops [3]. Drought is also a major factor in reducing the yield of rice under the rainfed field conditions [4]. According to Kumar et al. [5], rice yields under severe drought conditions can be reduced up to 65% in comparison to non-drought conditions. The impact of climate change is increasingly serious, and the lack of irrigation water becomes more severe in the paddy field areas in the delta and mountainous areas.

The most severely affected areas by the drought in Asia are in Eastern India and Nepal border areas, with more than 17 million ha of rainfed rice [6]. In India, severe drought occurred in 2002, which reduced the yield of rice by 22% compared to 2001 [7]. Several other areas also severely affected by drought are Northern Thailand and Laos, with about 3 million ha of rainfed rice land. Decreased annual rice yield due to drought in Northeastern Thailand is estimated at 10% to 35% [8]. In drought-prone areas, farmers tend to have little or no investment in fertilizer for crops that lead to poor soil nutrition. The average yield of rice in these areas is only about 2.3 tons/ha on the field and about 1 ton/ha on upland rainfed areas [1]. According to the statistics in 2002, the annual area of rice cultivation in Vietnam is about 7.3-7.5 million ha, of which 1.5-1.8 million ha are often lack of irrigation [9].

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There have been some studies on drought tolerant rice in the world [5, 10, 11]. In Vietnam since the 1990s, many drought-tolerant rice varieties have been selected by scientists through conventional breeding as well as biotechnology applications [12-14]. However, those results focus mainly in the North and South of Vietnam. Therefore, research and selection of drought-tolerant rice varieties adapted to the conditions of the Central Vietnam is a matter being raised by managers and scientists to produce and add to the structure of plant varieties, and improve efficiency in agricultural production for this region. The purpose of this study was to evaluate the drought tolerance of rice varieties collected from different sources in artificial drought condition and to assess the adaptation, growth and development of these varieties on rainfed rice field in Thua Thien Hue and Quang Nam province which were the representation of Central Vietnam.

2. Materials and Methods

Total 10 rice varieties collected from different locations were selected in this study (Table 1).

2.1 Experiment 1: Drought Tolerance Experiment in the Greenhouse

The seed was sown on the plastic tray until 3-4 leaves emerge, and these plants were then transplanted into plastic pot in the greenhouse with three seedlings for each pot, 10-12 cm for their distance. The experiment was designed by the randomized complete block (RCBD) with three replications. The greenhouse was covered by white plastic, and temperature was around 30-35 °C inside. The plant was irrigated from transplantation to booting stage.

Drought tolerance was evaluated according to Fischer et al. [15]. In the late booting stage of any tiller of one plant, the supply water was stopped. When soil surface of the pot dried, it was counted as the 1st day of artificial drought. On the 10th day of artificial drought, three plant samples/replication were taken for the root length, root fresh weight and root dry weight measurement in both irrigated and drought condition. The leaf rolling and leaf drying indicators were also evaluated in this time for drought condition (Tables 2 and 3) [16]. After 10 d artificial drought, water was supplied again in the plastic pot and recovery

Table 1 Origin of 10 rice varieties used in the study.

No.	Name of varieties	Origin/collection place
1	OM4900	Cuu Long Delta Rice Research Institute
2	OM7347	Cuu Long Delta Rice Research Institute
3	OM9915	Cuu Long Delta Rice Research Institute
4	IR93340	International Rice Research Institute
5	IR95172	International Rice Research Institute
6	GSR96	Ho Chi Minh City University of Agriculture and Forestry
7	GSR38	Ho Chi Minh City University of Agriculture and Forestry
8	SV181	Quang Binh Seed Company Limited
9	HT1	Thua Thien Hue Seed & Livestock Breeds Joint Stock Company
10	CH207	Center for Testing and Verification Plant Breeding, Plant Production Center of Central Vietnam

Table 2 Evaluation score of visual drought sensitivity.

Score	Leaf rolling	Leaf drying	Recovery (%)
0	Leaves healthy	No symptoms	-
1	Leaves start to fold	Slight tip drying	90-100
3	Leaves folding (deep V-shape)	Tip drying extended up to 1/4 length in most leaves	70-89
5	Leaves fully cupped (U-shape)	One-fourth to 1/2 of all leaves dried	40-69
7	Leaf margins touching (O-shape)	More than 2/3 of all leaves fully dried	20-39
9	Leaves tightly rolled	All plants apparently dead	0-19

of rice varieties were observed on the 10th day.

2.2 Experiment 2: Rainfed Rice Field Experiment

The rainfed rice field experiment of 10 rice varieties was conducted in two crop seasons of summer-autumn 2016 and winter-spring 2016-2017, respectively, in two provinces of Thua Thien Hue and Quang Nam.

The experiment was designed by the randomized complete block with each variety with three replications, 10 m^2 area for one replication. The 25-day old seedlings were transplanted using one seedling per hill at a spacing of 10 cm × 20 cm (density: 50 plants/m^2). The fertilizers applied for 1 ha were 800 kg Song Gianh microbial organic fertilizer (15% organic matter; 30% moisture; 1.5% P_2O_5; 2.5% humic acid; 3×10^6 CFU/g useful strain microbes; Ca, Mg, S included) (Song Gianh Corporation), 90 kg N, 60 kg P_2O_5 and 80 kg K_2O. Basal fertilizer was 100% microbial organic fertilizer, 100% P_2O_5 and 30% N for manuring. There were three times of top dressing: the 1st time (before tillering stage), applied 40% N and 30% K_2O; the 2nd time (10-12 d after the 1st time), applied 20% N and 40% K_2O; the 3rd time (22-12 d before flowering), applied 10% N and 30% K_2O.

The growth time (day), plant height (cm), total tiller per plant, panicle length (cm), number of filled spikelet per panicle, filled spikelet ratio (%), 1,000-grain weight (g) and yield (quintal/ha) were followed to the National Technical Regulation on Testing for Value of Cultivation and Use of Rice Varieties [17]. Ten plant samples/replications were measured. The growth duration (day) was counted from seed sowing to 85%-90% seed ripe of panicle. Plant height (cm) was measured from soil surface to tip of the tallest panicle, and awns excluded at mature stage. Panicle length (cm) was measured from panicle base to tip. The weight of 1,000 grains (g) was measured when the humidity of seed at 14% after harvesting. Filled spikelet ratio was calculated as Eq. (1):

$$\text{Filled spikelet ratio} = \frac{\text{No. of filled spikelet}}{\text{total spikelet}} \times 100\% \qquad (1)$$

2.3 Data Analysis

The differences of indicators between experimental varieties were compared by one-way analysis of variance (one-way ANOVA) at $\alpha = 0.05$ on software Statistix 9.0.

3. Results and Discussion

3.1 Leaf and Root Characteristics Related to Drought Tolerance of Rice Varieties under Irrigated and Artificial Drought Condition in the Greenhouse

According to Kumar and Singh [18], for cereals, especially rice, the reproductive phase, including pollinating and fertilization, is the most sensitive period, and the yield is most effected when lack of irrigation in the period. Leaf rolling and leaf drying are morphological indicators related to drought tolerance of rice. Leaf drying is one of the symptoms when rice is deficient in water [19].

The study results in drought condition in this study showed that different varieties had different leaf rolling and leaf drying (Table 3). The varieties with low leaf rolling and leaf drying were GSR96, GSR38, HT1 and CH207. These varieties also have high recovery after irrigation (90%-100%). The varieties with moderate recovery were OM7347 and IR93340 (40%-69%).

In addition to assessing leaf morphology, root characteristics also reflect the drought tolerance of rice. The root length is an important indicator affecting the water absorption capacity of rice [10, 20]. As shown in Table 4, under irrigated and drought conditions, the root length, root fresh and dry weight of the rice varieties differ greatly. In the same variety, the root indicators also differ in the conditions of irrigation and drought. For example, under irrigation conditions, the IR93340 variety had a root length of 20.33 cm, root fresh weight of 15.16 g/plant and root dry weight of 3.92 g/plant, but under drought conditions, the roots length had increased to 34.50 cm, the root fresh weight was 18.65 g/plant and the root dry

Table 3 Evaluation of drought tolerance and recovery of rice varieties in drought artificial condition.

Variety	Leaf rolling (score)	Leaf drying (score)	Recovery	
			(%)	Score
OM4900	3-5	1	90-100	1
OM7347	5-7	3-5	40-69	5
OM9915	3-5	3-5	90-100	1
IR93340	5-7	3-5	40-69	5
IR95172	5-7	0-1	90-100	1
GSR96	0-1	0-1	90-100	1
GSR38	0-1	0	90-100	1
SV181	7	1-3	90-100	1
HT1	0	0-1	90-100	1
CH207	1-3	1-3	90-100	1

Table 4 Root characteristics of rice varieties at flowering stage in irrigated and drought condition.

Variety	Irrigated condition			Drought condition		
	Root length (cm)	Root fresh weigh per plant (g)	Root dry weigh per plant (g)	Root length (cm)	Root fresh weigh per plant (g)	Root dry weigh per plant (g)
OM4900	36.33^{ab}	20.93^{c}	4.86^{cd}	31.53^{abc}	71.26^{a}	26.58^{a}
OM7347	33.00^{bc}	45.01^{b}	10.27^{cd}	33.27^{ab}	48.60^{abc}	14.24^{a}
OM9915	35.33^{abc}	19.10^{c}	22.88^{a}	24.80^{c}	31.85^{bc}	29.48^{a}
IR93340	20.33^{d}	15.16^{c}	3.92^{d}	34.50^{ab}	18.65^{c}	11.14^{a}
IR95172	21.97^{d}	25.70^{c}	8.91^{cd}	38.67^{a}	41.53^{abc}	8.38^{a}
GSR96	43.00^{a}	45.60^{b}	10.33^{cd}	36.27^{a}	48.63^{abc}	14.82^{a}
GSR38	34.73^{abc}	60.35^{b}	20.69^{ab}	27.75^{bc}	31.63^{bc}	18.87^{a}
SV181	27.33^{cd}	17.32^{c}	3.44^{d}	38.80^{a}	30.41^{bc}	8.12^{a}
HT1	37.35^{ab}	45.26^{b}	13.33^{bc}	27.20^{bc}	53.46^{abc}	16.20^{a}
CH207	38.17^{ab}	97.36^{a}	23.89^{a}	34.50^{ab}	59.31^{ab}	14.76^{a}
F test	6.14	18.58	6.87	2.94	1.70	0.62
CV (%)	15.56	26.30	41.83	14.94	48.16	95.45
$LSD_{0.05}$	8.74	17.67	8.79	8.38	35.96	26.62

Values in the same column with the same letter indicate no significant difference at $\alpha = 0.05$.

weight was 11.14 g/plant. The root length of CH207 variety in irrigated and drought conditions was not different (38.17 cm vs. 34.50 cm), but the root fresh weight in watering conditions was 97.36 g/plant, higher than that in drought conditions (59.31 g/plant). This indicates that the caused drought has affected the root characteristics of the variety. Under the caused drought conditions, root length was not correlated with root fresh weight, and the long-rooted length groups were SV181, IR95172, GSR96, OM4900 and OM7347.

3.2 Agronomic Characteristics and Yield of Rice Varieties under Inactively Irrigated Field Conditions

3.2.1 Morphological Characteristics of Rice Varieties

The morphological characteristics of rice varieties in inactively irrigated field experiment in Thua Thien Hue and Quang Nam province, representing the Central of Vietnam, for two years in 2016-2017 were shown in Tables 5 and 6.

The growth duration of varieties in summer-autumn 2016 (90-112 d) was shorter than that of winter-spring 2016-2017 (109-131 d), in Thua Thien Hue, while in

Table 5 Morphological characteristics of rice varieties in Thua Thien Hue province.

Variety	Summer-Autumn 2016				Winter-Spring 2016-2017			
	Growth time (d)	Plant height (cm)	Total tiller per plant	Panicle length (cm)	Growth time (d)	Plant height (cm)	Total tiller per plant	Panicle length (cm)
OM4900	92	92.3^{cd}	10.7^{abcd}	24.00^{ab}	110	98.8^{efg}	17.6^{bc}	25.4^{abc}
OM7347	99	92.1^{d}	11.7^{a}	24.33^{ab}	119	97.3^{fg}	21.9^{a}	24.3^{ab}
OM9915	94	94.9^{bcd}	9.8^{abcde}	21.00^{c}	113	100.3^{def}	18.5^{b}	23.2^{ab}
IR93340	97	97.2^{ab}	11.3^{abc}	24.33^{ab}	109	95.9^{g}	20.9^{a}	27.8^{c}
IR95172	91	93.5^{bcd}	9.5^{bcde}	24.17^{ab}	116	103.6^{cd}	17.7^{bc}	23.0^{ab}
GSR38	92	96.7^{ab}	8.9^{de}	25.3^{ab}	110	108.0^{b}	15.8^{c}	29.7^{bc}
GSR96	93	92.0^{d}	9.2^{cde}	24.7^{ab}	113	103.0^{cd}	17.5^{bc}	22.3^{abc}
SV181	90	99.2^{a}	11.4^{ab}	26.3^{a}	116	106.1^{bc}	20.8^{a}	23.3^{ab}
HT1	93	93.3^{abc}	8.3^{e}	23.7^{abc}	113	112.1^{a}	18.2^{b}	24.6^{a}
CH207	112	92.1^{d}	8.9^{de}	23.0^{bc}	131	101.1^{de}	17.4^{bc}	21.7^{a}
F test	-	3.54	2.96	2.41	-	17.34	5.97	2.21
CV (%)	-	2.51	12.23	6.54	-	2.02	7.46	5.89
$LSD_{0.05}$	-	4.06	2.09	2.70	-	3.56	2.11	2.31

Values in the same column with the same letter indicate no significant difference at $\alpha = 0.05$.

Table 6 Morphological characteristics of rice varieties in Quang Nam province.

Variety	Summer-Autumn 2016				Winter-Spring 2016-2017			
	Growth time (d)	Plant height (cm)	Total tiller per plant	Panicle length (cm)	Growth time (d)	Plant height (cm)	Total tiller per plant	Panicle length (cm)
OM4900	104	95.67^{ab}	10.6^{de}	19.33^{b}	114	100.07^{abc}	8.0^{a}	24.90^{ab}
OM7347	106	93.80^{abc}	14.6^{a}	21.33^{ab}	117	93.97^{c}	6.7^{ab}	23.03^{cde}
OM9915	104	98.57^{a}	11.5^{bcde}	21.67^{ab}	114	99.92^{abc}	6.7^{ab}	24.27^{bc}
IR93340	103	95.60^{ab}	13.6^{ab}	21.67^{ab}	107	95.93^{bc}	6.6^{ab}	21.43^{e}
IR95172	104	88.87^{bc}	9.7^{de}	20.67^{ab}	110	95.60^{bc}	7.3^{ab}	22.90^{cde}
GSR38	103	101.53^{a}	9.3^{e}	23.33^{a}	114	100.60^{abc}	5.3^{b}	22.43^{de}
GSR96	102	97.33^{a}	10.9^{cde}	23.67^{a}	117	95.10^{bc}	5.4^{b}	23.57^{bcd}
SV181	103	96.07^{ab}	9.6^{e}	20.67^{ab}	113	101.47^{ab}	7.1^{ab}	25.10^{ab}
HT1	105	97.07^{a}	12.1^{bcd}	21.33^{ab}	115	105.13^{a}	7.9^{a}	26.07^{a}
CH207	119	87.07^{c}	13.1^{abc}	21.00^{ab}	121	97.13^{bc}	8.5^{a}	24.10^{bcd}
F test	-	2.58	4.81	1.41	-	2.01	3.18	5.31
CV (%)	-	4.91	12.48	8.61	-	4.28	14.63	4.38
$LSD_{0.05}$	-	8.01	2.46	3.17	-	7.23	2.01	1.78

Values in the same column with the same letter indicate no significant difference at $\alpha = 0.05$.

Quang Nam, the growth duration was 102-119 d and 107-121 d, respectively. In both seasons, the CH207 variety had the longest growth period in the medium duration group. Thus, this variety is difficult to cultivate in the central provinces, especially in Thua Thien Hue, because the weather at the end of summer-autumn season is often flooding. The remaining varieties are suitable for local conditions of cultivation.

The plant height of these varieties was low-height group (90-110 cm), relatively suitable for the resistant rice varieties. The moderately plant height is more favorable where it is difficult to control water and resistant to falling [19]. The panicle length of varieties in the same crop had little difference. The tillering ability of the varieties in summer-autumn crop season was lower than that in winter-spring at the Thua Thien Hue site. The total tillers of the varieties in the summer-autumn crop ranged from 8.33 tillers/plant to 11.73 tillers/plant, while from 15.8 tillers/plant to 21.9

tillers/plant in winter-spring crop season. However, in Quang Nam, the total tillers of the varieties in summer-autumn crop varied from 9.3 tillers/plant to 14.6 tillers/plant, and from 5.3 tillers/plant to 8.5 tillers/plant in winter-spring. According to Yoshida [19], the difference in the number of tillers is due to the planting distance, environmental conditions, cultivation techniques and nutrient source. The OM7347 variety had the highest tillering ability among these varieties (11.7-21.9 tillers/plant). In winter-spring crop season in Quang Nam, the CH207 had the highest number of tillers (8.5), followed by OM4900 (8.0), however this difference is not statistically significant at $\alpha = 0.05$.

3.2.2 Yield Components of Rice Varieties

The filled spikelets rate had a great variation among varieties. The variety with the highest filled spikelets rate in the crops is OM4900 (77.4%-90.5%). In both Thua Thien Hue and Quang Nam provinces, OM9915 had the lowest percentage of filled spikelets in summer-autumn crop (60.7% vs. 65.9%) and GSR38 had the lowest percentage of filled spikelets in winter-spring crop (67.6% vs. 67.3%). In general, the percentage of filled spikelets in summer-autumn was lower than that of winter-spring crop. This study is in conformity with Sen et al. [21].

The 1,000-grains weight is less change and the most stable component yield of a variety, which is highly hereditary, but is also affected by external environment conditions. The 1,000-grains weights of rice varieties in winter-spring are higher than that in summer-autumn [22]. The 1,000-grains weight in summer-autumn crop in both Thua Thien Hue and Quang Nam was not largely variant among varieties. SV181 had low 1,000-grains weight (23.25 g vs. 21.87 g), and CH207 had the highest 1,000-grains weight (25.85 g vs. 27.33 g). In winter-spring, 1,000-grains weight varied less among the varieties, and the greatest one was CH207 (29.87 g vs. 32.29 g) (Tables 7 and 8).

Plant yield is the actual result of the experiment processing, demonstrating the adaptability of the variety to its external conditions, pest and disease resistance as well as other disadvantage conditions. The winter-spring crop season has favorable weather conditions for the growth and development of rice, therefore the yield is often higher than that in summer-autumn. It can be seen in Table 8 that in winter-spring 2016-2017, the yield of 44.67-66.60

Table 7 Yield components and yield of rice varieties in Thua Thien Hue province.

Variety	Summer-Autumn 2016				Winter-Spring 2016-2017			
	No. of filled spikelet per panical	Filled spikelet ratio (%)	1,000-grains weight (g)	Yield (quintal/ha)	No. of filled spikelet per panical	Filled spikelet ratio (%)	1,000-grains weight (g)	Yield (quintal/ha)
OM4900	114.2^{a}	80.5	24.65^{bc}	56.00^{a}	102.3^{bc}	90.5	27.67^{b}	53.77^{a}
OM7347	88.1^{de}	60.7	24.82^{abc}	49.33^{c}	119.4^{ab}	81.4	25.90^{cde}	42.33^{d}
OM9915	75.4^{f}	62.4	23.99^{cd}	37.02^{c}	119.1^{ab}	81.9	27.20^{bc}	49.00^{abc}
IR93340	95.7^{cd}	71.0	24.97^{ab}	56.33^{a}	95.9^{c}	77.6	25.53^{de}	47.00^{bcd}
IR95172	85.5^{ef}	73.7	23.16^{d}	49.32^{c}	113.9^{bc}	74.6	26.23^{bcde}	44.67^{cd}
GSR38	97.8^{cd}	72.3	25.71^{a}	52.30^{bc}	115.5^{abc}	67.6	26.93^{bcd}	53.67^{a}
GSR96	90.3^{de}	70.3	23.45^{d}	51.33^{bc}	120.1^{ab}	78.3	25.27^{e}	52.33^{ab}
SV181	108.1^{ab}	72.1	23.25^{d}	51.30^{bc}	133.5^{a}	80.2	25.13^{e}	53.33^{a}
HT1	102.8^{bc}	66.2	24.62^{a}	53.01^{ab}	109.1^{bc}	75.6	25.53^{de}	49.00^{abc}
CH207	84.3^{ef}	70.6	25.85^{a}	51.67^{b}	96.4^{c}	85.1	29.87^{a}	49.67^{abc}
F test	12.02	-	9.05	25.80	2.65	-	9.15	4.99
CV (%)	6.28	-.	2.38	3.63	10.84	-	3.14	6.18
$LSD_{0.05}$	10.14	-	0.99	3.17	20.24	-	1.46	5.42

Values in the same column with the same letter indicate no significant difference at $\alpha = 0.05$.

Table 8 Yield components and yield of rice varieties in Quang Nam province.

Variety	Summer-Autumn 2016				Winter-Spring 2016-2017			
	No. of filled spikelet per panical	Filled spikelet ratio (%)	1,000-grains weight (g)	Yield (quintal/ha)	No. of filled spikelet per panical	Filled spikelet ratio (%)	1,000-grains weight (g)	Yield (quintal/ha)
OM4900	110^{ab}	77.4	24.83^{bc}	40.33^{bc}	112.6^{bc}	86.8	25.76^{de}	61.56^{ab}
OM7347	86.6^{ab}	74.7	23.47^{cde}	43.66^{ab}	107.8^{cd}	86.1	26.27^{cd}	66.60^{a}
OM9915	100.9^{ab}	65.9	24.20^{cd}	41.66^{abc}	101.3^{d}	85.7	26.67^{bc}	55.47^{b}
IR93340	92.1^{ab}	75.4	23.17^{cde}	43.66^{ab}	79.1^{f}	86.9	24.35^{f}	44.67^{d}
IR95172	79.5^{b}	71.1	23.07^{cde}	37.33^{cd}	106.5^{cd}	80.5	24.38^{f}	45.93^{cd}
GSR38	101.3^{ab}	71.7	26.53^{cd}	45.66^{a}	112.9^{bc}	67.3	26.65^{bc}	64.87^{a}
GSR96	115.3^{a}	78.3	23.80^{ab}	45.33^{a}	119.1^{ab}	75.8	26.92^{b}	55.47^{b}
SV181	109.7^{ab}	79.6	21.87^{e}	35.33^{d}	127.8^{a}	75.9	25.38^{e}	58.93^{ab}
HT1	88.3^{ab}	75.5	22.43^{de}	45.00^{a}	127.7^{a}	87.6	25.32^{e}	54.47^{bc}
CH207	98.6^{ab}	74.0	27.33^{a}	40.00^{bc}	90.5^{e}	82.9	32.29^{a}	58.00^{ab}
F test	1.00	-	7.29	5.10	18.80	-	1.13	5.28
CV (%)	20.38	-	4.63	6.47	5.66	-	1.22	9.55
$LSD_{0.05}$	34.34	-	1.91	4.64	10.55	-	0.55	9.28

Values in the same column with the same letter indicate no significant difference at $\alpha = 0.05$.

quintals/ha was higher than that in summer-autumn 2016 (35.33-45.66 quintals/ha) in Quang Nam. However, in Thua Thien Hue, the yield in this two crop seasons was not greatly different. The yield in summer-autumn 2016 was 37.02-56.33 quintals/ha and 42.33-53.67 quintals/ha in winter-spring 2016-2017. However, the yield of this summer-autumn crop varied more largely than the winter-spring crop.

Some varieties with fairly high yields in both summer-autumn 2016 and winter-spring 2016-2017 in Thua Thien Hue province were OM4900 (56.00 quintals/ha vs. 53.77 quintals/ha), GSR38 (52.30 quintals/ha vs. 53.67 quintals/ha) and IR93340 (56.33 quintals/ha vs. 47.00 quintals/ha), while in Quang Nam was OM7347 (43.66 quintals/ha vs. 66.60 quintals/ha), GSR38 (45.66 quintals/ha vs. 64.87 quintals/ha) and OM4900 (40.33 quintals/ha vs. 61.56 quintals/ha) (Tables 7 and 8). The GSR96 variety was also a high yielding one in both crop seasons, however, the purity of this variety was very low during the observation in the field. It should be reselected for better quality seed. The promising varieties above should continue to be tested on larger areas in inactively irrigated fields to evaluate the potential of the variety exactly.

Research by Fischer et al. [15] suggested that leaf drying was associated with yield under disadvantage conditions. However, the present research have found that in high field yield varieties of OM4900, OM7347, IR93340 and GSR38, there were only two varieties OM4900 and GSR38 as low leaf drying (score 0-1) and high recovery (90%-100%; score 1). The other two varieties OM7347 and IR93340 had a medium leaf dryness (score 3-5) and moderate recovery (40%-69%; score 5) when watering again. Thus, it can be said that plant yield depends on many components, so the indicators related to the drought tolerance of rice can not reflect all the productivity of the plant.

4. Conclusions

The rice varieties reseached in this study had different leaf rolling and leaf drying expression in drought condition. The most of these varieties were well recovered after irrigation (90%-100%). The drought has affected root characteristics of rice varieties through root length, root fresh weight and root dry weight. The long-rooted length groups were SV181, IR95172, GSR96, OM4900 and OM7347.

In two crop seasons, in Thua Thien Hue and Quang

Nam provinces, the rice varieties grew and developed well. Growth duration of varieties were from 90 d to 119 d in summer-autumn 2016 and from 107 d to 131 d in winter-spring 2016-2017. The yield of rice varieties in summer-autumn 2016 varied in 37.02-56.33 quintals/ha and 42.33-66.60 quintals/ha in winter-spring 2016-2017. Some varieties with fairly high yields in both summer-autumn 2016 and winter-spring 2016-2017 crops in Thua Thien Hue province were OM4900, GSR38 and IR93340, while in Quang Nam province was OM7347, GSR38 and OM4900. These rice varieties also had rather drought tolerance. Therefore, it is sugessted to conduct production experiment on a large area in rainfed field for above these varieties to evaluate them objectively and early put them into structure of rice varieties in Central Vietnam.

Acknowledgments

The authors would like to express sincere thanks to Vietnam Ministry of Education and Training for supporting research grant No. B2016-DDHH-26.

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