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Drought-tolerant characters, yield and its component of an elite landrace upland rice cultivars in Thailand

Sarutayophat, T.[1] *, Imwichit, S.[1], Sripichitt, A.[1], Phimsirikul, P.[1], Thabthimtho, T.[1] and Promsomboon, P.[2]

[1]Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand; [2]Department of Plant Science, Faculty of Agriculture and Natural resource, Rajamangala University of Technology Tawan-Ok, Chonburi, Thailand.

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Abstract In Thailand, rice are cultivated on the rainfed unbunded upland environment about 0.928 million ha annually, which usually subject to drought stress due to an eratic rainfall throughout growing season, and usually having low yield stability and productivity. Two experiments were characterized a drought tolerant-related physiological traits, yield and its components of 6 elite landrace upland rice cultivars (Niaw Dum Luem Phua, Dawk Pa Yawm, hukaothong 2, Sew Gliang, Sam Deuan, and Leb Nok) with IR1552, and Khao Dawk Mali 105, a moderate drought-tolerant check varieties. The first experiment was carried out at King Mongkut's Institute of Technology Ladkrabang, Bangkok during Aug-Sep 2018 for 4 drought tolerant-related characters at maximum tillering including longest root, root dry weight, root/shoot dry weight ratio, and stomatal conductance. The germinated seeds were grown in a cylindrical like-shape plastic pots, data were recorded for 10 hill/experimental unit. The second experiment was conducted at the experimental field of Rajamangala University of Technology Tawan-Ok, Chon Buri province, on loammy-sand, unbunded upland field under natural rainfed in rainy season (Jul-Nov), 2018. Ungerminated seeds were directly planted with space of 25x25 cm, yield and yield components were sampling recorded for 10 hill/experimental unit. All studied characters among cultivars; longest root, root/shoot dry weight ratio, stomatal conductance, yield and all yield components except, root dry weight were highly significant different ($p \leq 0.01$). IR1552 had the highest yield of 72.52 g/hill. Among 6 landrace cultivars, Niaw dum luem phua showed the highest drought tolerant-related characters, yield components, and rough yield of 59.77g/hill. While, Khao Dawk Mali 105 had rough yield of 51.42 g/hill.

Keywords: Drought-tolerant character, Elite landrace cultivar, Upland rice, Yield component

Introduction

Rice is the most humans consumed food crops, its being consumed by more than half of the world's population (Ricepedia, 2019; Saito *et al.*, 2018). It is grown in more than a hundred countries worldwide, with the total harvested

* **Corresponding Author:** Sarutayophat, T.; **Email:** teerawat.sa@kmitl.ac.th

area in the 2017/2018 crop year was 161 million hectares, producing more than 487 million tons of milled rice which 90% are produced and consumed in Asia (Ricepedia, 2019). Over 50% of the world's rice cultivated area are rainfed, but these nonirrigated area produced only a quarter of total rice production because more than 70% of these rainfed area are subject to drought stress any time during growing in the field and other abiotic factors. Among various stresses, such as soil pH, salt, drought, flood, heat, cool etc., drought is a major factor frequently imposes serious affects on growth, development, and yield productivity of the rainfed-rice production (Mishra and Panda, 2017). Rice is very sensitive to drought because of its semi-aquatic nature and high water requirements for its cultivation that make more prone to lose from drought stress than other cereals. Worldwide rice productivity is high variation range from less than 1 t/ha under very poor rainfed conditions to more than 10 t/ha in intensive temperate irrigated systems (Ricepedia, 2019). Dry conditions can occur at almost any time during the rice growth period in rainfed area leading to drought stress of varying intensity. The degree of droght effect on rice growth and yield depends on the severity of drought, growth stage of the rice plant that subjects to drought stress, and rice genotypes. A common adverse affect of drought is the reduction in the photosynthetic rate of physiological and biochemical processes (Usman *et al*., 2013) that lead to reduction in growth and yiled productivity. Severely drought stress can result in death of the rice plants (Nahar *et al*., 2018). Vigorous root growth is the most important adaptation to drought stress of rice and all plant species because roots are physiological organ that uptakes water and plant nutrients. Kanbar *et al*. (2009) stated that the longest root and dry root weight were significantly positive relation to drought tolerance capability in upland rice.

In Thailand, before middle of the 20th century, landrace varieties were grown in rainfed area across the country because of well adapt to environmental conditions and its nature in relative high drought-tolerant. However, In recent decade, these varieties were replaced by a new improved fertilizer-responsive high-yielding varieties that well adapted to the irrigated ecosystems and intensive production management. These new improved varieties were also being grown in a rainfed area thoughout the country eventhough its had never been screened for tolerant to drought stress. In recent years, rainfall in Thailand are more and more variation, the productivity of these new improved varieties were likely more serious loss than the relative drought-tolerant landraces, its usually heavy loss yield even under mild stress condition. The use of a drought-tolerant with high yield potential varieties is an important key strategy in reducing risk, increasing productivity, and alleviating poverty among a rainfed-rice farmers.

There are some elite landrace upland rice varieties that is still being grown by rural Thai farmers under rainfed ecosystems. These varieties should be evaluated for drought tolerant and other desired traits. However, the report on drought tolerant and yield productivity under natural drought stress are limited. We employed these experiments to characterize the physiological traits that highly related to drought-tolerant and yield potential under natural rainfall distribution of 6 elite landrace upland rice cultivars of Thailand.

Materials and methods

Genetic materials

Eight rice cultivars, including 6 elite landrace upland ones that are popular among rural rainfed farmers comprising of 1) Niaw Dum Luem Phua, 2) Dawk Pa Yawm, 3) Phukaothong 2, 4) Sew Gliang, 5) Sam Deuan and 6) Leb Nok, and 2 check moderately drought tolerant cultivars; IR1552, and Khao Dawk Mali 105 were evaluated for drought tolerant and yield potential under natural rainfed condition. These 6 upland rice cultivars were drought tolerant (HRDI, 2019) and better adapted to the rainfed-unbunded upland cultivated area than the lowland rice variety. Khao Dawk Mali 105 was the most famous aromatic rice variety in Thailand, its milled rice was premium and most demanded in global market. It was moderately tolerance to drought (Rice Department, 2019).

Procedure

This study was conducted to characterize an agronomic traits that relation to drought tolerant, and evaluate yield, yield components of total 8 rice varieties. Two experiments were carried out separately in rainy season, 2018. The first experiment was conducted to characterize traits at the maximum tillering stage that relation to drought tolerant, and the second experiment was yield tested under natural rainfall of an upland unbounded environment.

Characterization the drought-tolerant relation characters

The first experiment was conducted in the opened roof greenhouse at King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand, using a Completely Randomized Design (CRD) with 3 replications. The germinated seeds were sown in cylindrical like-shape, black plastic pots for 2 seeds/hill, 5 hills/pot, 6 pot/experimental unit. Plastic pot size of 14 inch in diameter and height with a hole at its base for water or rainfall drainaged. The growing media used in the experiments was the mixture of coarse-sand, loamy soil and composted leaves of *Samanea* sp. in ratio of 1:1:1, and each plastic pot contained 20 kg of prepared media. After 14 days seedling were thinned to 1 seedling/hill. Chemical fertilizer formular 15-15-15 was applied for 3.125 g/pot (156.25 kg/ha) at 14 days after germination. Mostly water used in this experiment was the natural rainfall in rainy season (Aug-Sep), additional water supplied was considered in case of a long time lagging rainfall and rice seedling showing serious water deficit (leaves rolled in early morning). The main variable traits relation to drought stress tolerant were stomal conductant, longest root, root dry wt and shoot dry wt. The variable traits were recorded at the maximum tillering stage, 40-days after planting (DAP) for 10 plants/experimental unit.

Yield trial on rainfed-upland environment

The second experiment was conducted to evaluate yield and yield components of upland rice varieties. The experiment was tested on loammy-sand, unbunded upland field under natural rainfall at the experimental field of Rajamangala University of Technology Tawan-Ok, Chon Buri province, Thailand in rainy season (15 Jul-30 Nov), 2018. Randomized Complete Block Design (RCBD) with 3 replications was used. Ungerminated seeds were directly planted in space of 25x25 cm for 7-8 seeds/hill, 12 hills/row, 5 rows/experimental unit. Three weeks after planting seedling were thinned to 5 plants/hill. Chemical fertilizer formular 15-15-15 total of 312.5 kg/ha (50 kg/rai) was equally divided applied at beginning tillering, floral initiation, and pre-heading or about 3, 7, 11 weeks after planting, respectively. Yield components and grain yield were sampling recorded for 10 hills/experimental unit at 3-5 days after physiological maturity. Recorded data were analysis of variances and means of treatments were compared by Duncan's multiple range test (DMRT).

Rainfall distribution during field tested

Total rainfall thoughout 158 days of field experiment was 922.0 mm/crop and the days that rain falled more than 10 mm/day were total of 22-days along the cultivated period. Rainfall was high variation along with growing season. In late season, especially during late grain filled to harvesting, rainfall-limited occurred (Figure 1), water stress were subjected to rice varieties of the experiment and affected to grain weight accumulation that was flavour condition for drought tolerant evaluation of rice germplasm.

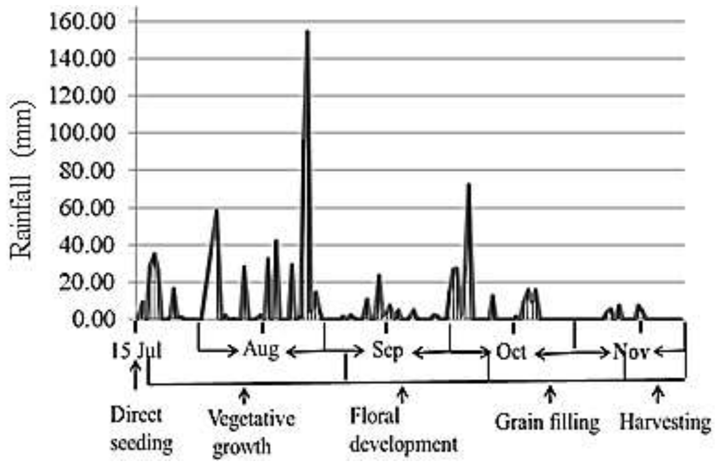

Figure 1. Rainfall distribution during field experiment in the rainy season, 2018

Results

Physiological characters relation to drought tolerant

Four physiological characters that related to drought tolerant among 6 upland rice and 2 check varieties were shown in Table 1. The longest root, root/shoot dry weight ratio and stomatal conductant at maximum tillering stage among tested varieties were hightly significant different ($p \leq 0.01$). While, root dry weight of all tested varieties were non-significant different (Table 1). IR1552 had longest root of 44.13 cm, was non-significant different to the longest root of Dawk pa yawm, Leb nok, Phukaothong 2, Niaw dum luem phua, Sam deuan, and Khao Dawk Mali 105 which longest roots were 38.53, 36.46, 33.76, 33.63, 33.60 and 32.17 cm, respectively. Niaw dum luem phua had highest root dry weight of 25.06 g/hill, Sam deuan was second place of 22.20 g/hill while IR1552, Khao dawk mali 105 and Phukaothong 2 had almost equal root dry weight of 20.45-20.55 g/hill, and Sew gliang had a non-significant different lowest of 16.83 g/hill (Table 1). Root/shoot dry weight ratio of IR1552, Khao Dawk Mali 105, Niaw dum luem phua, Dawk pa yawm and Sam deuan were non-significant different of 0.54, 0.48, 0.49, 0.38 and 0.49 respectively. While, Phukaothong 2, Sew gliang and Leb nok had a significant lower root/shoot dry weight ratio than IR1552 of 0.37, 0.37 and 0.34, respectively. IR1552 and Sam deuan had almost equal stomatal conductant of 1.51 and 1.52 mmol $m^{-2}s^{-1}$ which significantly lower than others ($p \leq 0.01$).

Table 1. Longest root, root dry weight, root/shoot dry weight ratio, and stomatal conductant of 6 landrace upland rice cultivars with IR1552 and Khao Dawk Mali 105, the 2 check varieties

varieties	Longest root (cm)	Root dry wt (g/hill)	Root/shoot dry wt ratio	Stomatal conductant (mmol $m^{-2}s^{-1}$)
IR1552	44.13[a]	20.48	0.54[a]	1.51[c]
Khao dawk mali 105	32.17[abc]	20.55	0.48[ab]	1.70[a]
Niaw dum luem phua	33.63[abc]	25.06	0.49[ab]	1.65[ab]
Dawk pa yawm	38.53[ab]	18.80	0.38[ab]	1.60[b]
Phukaothong 2	33.76[abc]	20.45	0.37[b]	1.71[a]
Sew gliang	27.63[bc]	16.83	0.37[b]	1.71[a]
Sam deuan	33.60[abc]	22.20	0.49[ab]	1.52[c]
Leb nok	36.46[abc]	17.39	0.34[b]	1.62[b]
F-test	**	NS	**	**
CV (%)	13.47	21.11	13.27	1.58

Means within column followed by the same letter indicated a non-significant difference between varieties by DMRT
** = significant difference at $p \leq 0.01$
NS = non-significant difference

Culm height and dry weight

The culm height and straw dry weight among 8 rice varieties were significant different ($p \leq 0.01$). Six landrace upland rice and Khao dawk mali 105 were medium culm height in upland condition their culm height were non-significant different, varied from 93.63 to 101.53 cm. Anyway, their culm were significantly higher than IR1552 which culm height was 59.13 cm. Resulted of straw dry weight was similar to culm height. Khao dawk mali 105 and 5 upland rice, excepted Niaw dum luem phua had non-significant different straw dry weight varied from 48.60-92.91 g/hill, higher than Niaw dum luem phua and IR1552 which straw dry weight were 41.16 and 40.50 g/hill, respectively.

Yield components

All 6 studied yield components; number of panicles/hill, panicle length, number of total spikelets/panicle, number of filled grains/panicle, filled grain percentage, and 1,000-seeds weight of 8 rice varieties were significant different ($p \leq 0.01$). IR1552 had highest panicles/hill of 21.20, Niaw dum luem phua and Sew gliang were the second and the third place of 15.80 and 11.60 panicles/hill which non-significant different to the highest. While, Phukaothong 2 had lowest amount of 7.66 panicles/hill (Table 2). IR1552 had the shortest panicle of 20.63 cm, significantly shorter than the others tested cultivars ($p \leq 0.01$). Leb nok had longest panicle length of 30.22 cm, and the others 5 upland cultivars had various panicle length from 24.59-28.34 cm.

Table 2. Growth, number of panicles/hill, and panicle length of 6 landrace upland rice cultivars tested with IR1552 and Khao Dawk Mali 105, the 2 check varieties in rainy 2018

Varieties	Culm ht (cm)	Straw dry wt (g/hill)	No. of panicles/hill	Panicle length (cm)
IR1552	59.13[b]	40.50[b]	21.20[a]	20.63[d]
Khao Dawk Mali 105	101.40[a]	62.05[ab]	8.60[b]	24.56[c]
Niaw dum luem phua	97.46[a]	41.16[b]	15.80[ab]	25.65[bc]
Dawk pa yawm	101.53[a]	48.60[ab]	8.80[b]	26.06[bc]
Phukaothong 2	101.10[a]	64.62[ab]	7.66[b]	28.34[ab]
Sew gliang	93.83[a]	62.82[ab]	11.60[ab]	24.59[c]
Sam deuan	93.63[a]	64.49[ab]	9.36[b]	26.32[bc]
Leb nok	101.46[a]	92.91[a]	8.66[b]	30.22[a]
F-test	**	**	**	**
CV (%)	4.18	20.95	23.26	4.41

Means within column followed by the same letter indicated a non-significant difference between varieties by DMRT

** = significant difference at $p \leq 0.01$

The number of total spikelets/panicle and number of filled grains/panicle among cultivars were significant different ($p \leq 0.01$). Niaw dum luem phua had highest total spikelets/panicle and filled grains/panicle of 690.60 spikelets/panicle and 537.09 grains/panicle while, Sew gliang had lowest of 167.78 spikelets/panicle and 108.09 grains/panicle (Table 3). Percentage of filled grain among tested cultivars varied from 60.52% in Khao Dawk Mali 105 to 77.02% in Niaw dum luem phua. Thousand seeds weight among tested cultivars was significant different. Niaw dum luem phua and Sew gliang were 2 upland cultivars that had non-significant different seeds weight of 35.9 and 33.4 g/1,000 seeds, respectively. However, its seed weight were significant higher than the others which seed weight varied from 21.3 to 26.9 g/1,000 seeds (Table 3).

Grain yield

Grain yield among 8 rice varieties were significant different ($p \leq 0.01$). IR1552, Niaw dum luem phua, Dawk pa yawm, Khao Dawk Mali 105 and Sam deuan were the top 5 yield produced varieties. Their rough yield were non-significant different of 72.52, 59.77, 56.75, 51.42 and 50.52 g/hill, respectively (Table 3). Phukaothong 2 had the lowest yield of 35.63 g/hill, that might due to its lowest in number of panicle/hill (7.66), 1,000-seeds weight (21.3 g), and the 2nd place-lowest in filled grain percentage (61.85%). Under natural rainfed, loammy-sand and unbunded-upland condition, Niaw dum luem phua was the best adapted cultivar among the tested-landrace upland rice cultivars. It had the highest root dry weight (25.06 g/hill), number of total spikelets/panicle (690.60 spikelets), number of filled grains/panicle (537.09 grain), percentage of filled grain (77.02%), and 1,000-seed weight (35.9 g) that impacted to its best yield among upland rice. Dawk pa yawm produced the second-highest yield (56.75 g/hill) among landrace upland rice with non-significant different to the highest yield of all tested varieties.

Table 3. Yield components and yield of 6 landrace upland rice cultivars tested with IR1552 and Khao Dawk Mali 105, the 2 check varieties in rainy 2018

Varieties	No. of total spikelets/ panicle	No. of filled grains/ panicle	Filled grain percentage (%)	1,000-seeds wt (g)	Grain yield (g/hill)
IR1552	471.59^{ab}	344.23^{ab}	69.91^{ab}	23.2^{c}	72.52^{a}
Khao Dawk Mali 105	370.57^{ab}	224.23^{b}	60.52^{b}	26.9^{b}	51.42^{ab}
Niaw dum luem phua	690.60^{a}	537.09^{a}	77.02^{a}	35.9^{a}	59.77^{ab}
Dawk pa yawm	375.98^{ab}	232.38^{b}	68.61^{b}	22.3^{c}	56.75^{ab}
Phukaothong 2	487.23^{ab}	302.26^{ab}	61.85^{b}	21.3^{c}	35.63^{b}
Sew gliang	167.78^{c}	108.09^{c}	64.46^{ab}	33.4^{a}	40.48^{b}
Sam deuan	332.55^{ab}	216.60^{b}	65.53^{ab}	21.6^{c}	50.52^{ab}
Leb nok	485.81^{ab}	352.93^{ab}	72.85^{ab}	22.1^{c}	45.94^{b}
F-test	**	**	**	**	**
CV (%)	23.59	25.61	7.03	6.23	25.77

Means within column followed by the same letter indicated a non-significant difference between varieties by DMRT
** = significant difference at $p \leq 0.01$

Discussion

Vigorous root growth is the important adaptation to drought stress of an upland rice and all plant species because roots are physiological organ that uptakes water and plant nutrients. Low leaf stomatal conductivity is the physiological mechanism in decreasing water lost by transpiration through stomata, increasing water use efficiency. Genotypes that have low stomatal conductivity are tend to express a high tolerant to drought stress. It has been noted that drought tolerant in a crops is very complicate and difficult to identify degree of the association of each physiological trait to drought stress availability (Song *et al*., 2006; Zu *et al*., 2017). There are many indices of drought tolerance have previously been proposed for use in identification and selection of drought tolerant genotypes in various crop. Kanbar *et al*. (2009) proposed that longest root and root dry weight were highly related to drought tolerant of an upland rice. Based on 4 drought tolerant related traits in this studied, indicated that IR1552 had highest drought-tolerant potential, followed by Sam deuan, Dawk pa yawm and Khao dawk mali 105. A short culm genotype was desirable because it has been confirmed of its higher sturdy culm and tolerant to lodging than a long culm rice genotypes (Tomita and Tanisaka, 2010). A recent trend in rice breeding has been development of the semidwarf rice cultivars, which are suitable for high density cultivation with intensive use of fertilizers. These cultivars typically feature a short sturdy culm, multiple tillers and upright leaves, and their high productivity has been reported in numerous studies (Tomita and Tanisaka, 2010).

Grain yield of an upland rice under natural rainfed unbunded-upland condition were associated to the drought tolerant-related physiological traits and the important yield components. The results of this study suggested that the longest root, root dry weight, root/shoot dry weight ratio, and stomatal conductant were important physiological traits that highly associated to the drought tolerant in rice genotypes. The number of panicle/hill, number of total spikelets/panicle, number of filled grains/panicle, and 1,000-seeds weight were 4 important yield components of an upland rice genotypes. Niaw dum luem phua was the best adapted-cultivar among 6 landrace upland rice. Its yield under natural rainfed was 59.77 g/hill with the highest root dry weight, number of total spikelets/panicle, number of filled grains/panicle, percentage of filled grain, and 1,000-seed weight.

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