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Selection for Upland Rice Varieties Under Different Levels of Light Intensity

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ABSTRACT

Upland rice varieties were selected under varying levels of light intensity. This study identified shade-tolerant upland rice varieties with a high yield. From November 2016 to March 2017, the experiment was conducted at King Mongkut's Institute of Technology in Ladkrabang, Prince of Chumphon, Thailand. For this, ten varieties of upland rice i.e. Dawk Pa-yawm, Nangdam, Dokkam, Nangchuan, Lebnokrai, Samduen, Maepeung, Damgatondom, Lebmuenang, Pukaotong were grown at different levels of 0%, 50%, 60%, and 70% shading levels. The experiment was conducted in a randomized complete block design with four replications. The results of qualitative characteristics indicated that shadowing conditions didn't have any significant effect on plant height, 50% flowering age, harvesting age, and panicle length. On the other hand, shaded conditions have a substantial effect on the number of plants per tiller, the number of panicles per tiller, the number of perfect grains per panicle, and the amount of empty grain per panicle since there was a quantitative character. Among the tested varieties, Lebmuenang, Pukaotong, Damgatondom, and Nangchuan varieties are suited for growing under 50% shade conditions while Samduen was only suited for cultivation in 70 % shaded conditions, whereas Pukaotong was good for growing in 50% and 60% shade situations. The results of this experiment did not encourage farmers to use the other varieties as cultivars under shaded conditions due to low yields. However, the outcomes of this study can be used as a reference for breeding programs in low-light conditions.

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1 Introduction

Farmers in the southern region of Thailand plant upland rice (*Oryza sativa* L.) as an alternative crop for home consumption (Nokkoul and Wichitparp 2013). It is grown in a variety of environments as a monoculture and as an intercropping with other 1-3 years old crops such as palm oil, coconut, rubber, and fruit plantations (Nokkoul 2017). If these crops are more than three years old, they could not allow any crop to grow as an intercrop. Further, environmental factors, particularly under shade conditions also, determine the essential characteristics of rice cultivation (Liu et al. 2014). It is one of the challenges that must be solved in the development of upland rice growing as an intercrop plantation (Jonatan et al. 2015). Low light can disrupt various physiological metabolisms, including photosynthetic characteristics of rice plants, activities of antioxidant enzymes in rice leaves, and key enzymes involved in starch production in grains (Liu et al. 2014). Further, Jonatan et al. (2015) reported that shaded condition reduces the number of tillers and panicles in upland rice varieties, reduced the panicle growth (Wang et al. 2018), decreases the number of productive grains, grain output per hill, and overall sugar content of upland rice plants. The development of highland rice agriculture in the shade of tree stands necessitates the development of early-duration rice varieties with a moderate range of 80 to 120 days and plant heights of 110 - 125 cm (Jonatan et al. 2015).

The purpose of this experiment was to identify upland rice varieties that could provide yield under shade and could be planted as an intercrop for further testing in association with 5 to 10 years old rubber plantations, or with 8 to 25-year-old oil palm plantations, or with 10 to 20-year-old fruit crops. This maximizes the use of space between the primary rows of plants. This will have an effect on household and community food security in Thailand's southern region.

2 Materials and Methods

Ten varieties of upland rice including Dawk Pa-yawm, Nangdam, Dokkam, Nangchuan, Lebnokrai, Samduen, Maepeung, Damgatondom, Lebmuenang, and Pukaotong have been selected for this study. All the varieties had passed selection by the mass selection method by King Mongkut's Institute of Technology Ladkrabang Prince of Chumphon Campus, Chumphon province, Thailand (10°43'26.1"N 99°22'28.5"E of 26.00 m. above the sea level). The seeds were planted to select varieties that could produce satisfactory high yields under black-net houses at the King Mongkut's Institute of Technology Ladkrabang Prince of Chumphon Campus Chumphon Province, Thailand from November 2016 to March 2017.

The experiments were performed under 4 shade conditions i.e. no shade treatment (natural light), 50% of the black-net house, 60% of the black-net house, and 70% of the black-net house. All treatments were applied at the rate of 200 kg/ acre of cow manure, and zeolite was applied at the rate of 20 kg/acre (mixed into the soil before growing). Upland rice seeds were sown per hole at a spacing of 25 cm within rows and 30 cm between rows, with three rows of cultivation of each variety (1.5 m long per row). The plants were thinned to two plants per hole 14 days after germination. The fertilizer (15N-15P-15K) was applied at a rate of 14 kg/acre at the ages of 20 and 40 days after seedling emergence. Weeding was eliminated either by hoe least twice, at the ages of 20 and 40 days after seed germination and watered once per week.

The study used a randomized complete block design (RCB) with four replications and was compared by Duncan's Multiple Range Test (DMRT). Plant height, days to 50% flowering, days to grain harvesting, number of plants per tiller, number of panicles per tiller, panicle length, number of perfect grains per panicle, number of empty grains per panicle, and grain yield (reduced moisture content by hot air oven at 43^{o}C for 48 hours for moisture content of 14%, following the IRRI (2002) standard procedure.

Data were analyzed to find suitable varieties focus on yield per area of each variety (yield is not less than 50% compared to varieties under 0% shading). The environmental data included light intensity and temperatures were taken with a HOBO Pendant Temperature/Light Data Logger (Part # UA-002-XX) at the plant's height, as well as rainfall amount measured with an ordinary rain gage.

3 Results

Results presented in figure 1 depict the average rainfall and temperature from November 2016 to March 2017, as well as the amount of light intensity received by rice plants from December 2016 to March 2017. Tables 1–5 indicate the plant height, days to 50% flowering age, days to grain harvesting, number of plants per tiller, number of panicles per tiller, panicle length, number of perfect grains per panicle, number of empty grains per panicle, and grain yield per growing area of ten upland rice varieties. The yield of ten varieties of upland rice grown under varying levels of light intensity in the summer was the focus of the data analysis. The results revealed that the grain yield of ten upland rice varieties with 0% shadowing (natural light) were significantly different among the treatments (Table 5). The Nangchuan variety had the maximum yield of 125.84 kg/acre under these conditions. It is advised that it can be grown in natural light settings (0 % shading). Dawk Pa-yawm, Nangdam, Samduen, Lebmuenang, and Pukaotong varieties had a yield of 88.60, 92.44, 93.47, 88.40, and 85.50 kg/acre, respectively, and these were not significantly different from the Nangchuan variety. Under 50% of shading conditions, Lebmuenang, Pukaotong, Damgatondom, and Nangchuan had yields of 98.80, 98.73, 96.28, and 95.80 kg/acre, respectively and all these four varieties are suitable to grow in dry season under 50% shading conditions. The

cultivation of upland rice at 60% shading, Nangchuan, Damgatondom, and Pukaotong upland rice varieties had a yield of 64.32, 50.43, and 48.78 kg/acre, respectively. All three varieties are suitable to grow in the dry season under 60% shading conditions. The cultivation of upland rice at 70% shading in Nangchuan, Samduen, and Damgatondom had a yield of 45.08, 42.16, and 39.23 kg/acre, respectively. Among the tested varieties, Samduen was suitable to grow in the dry season under 70% shading conditions.

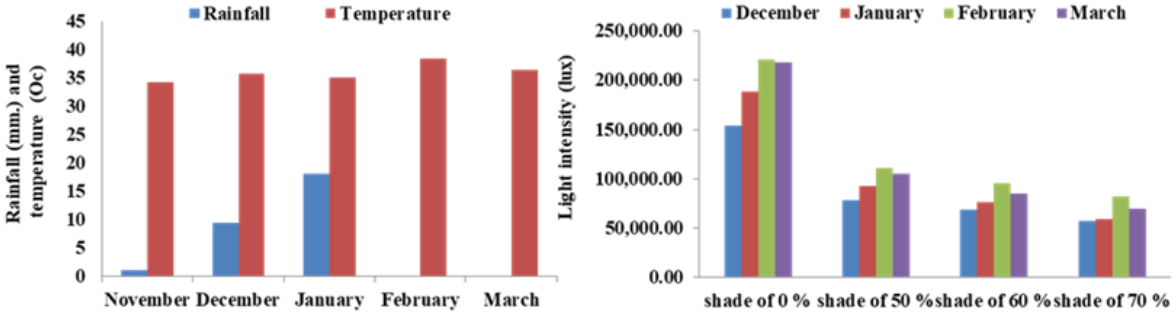

Figure 1 The average rainfall, temperature, and light intensity from November 2016 to March 2017.

Table 1 Plant height and flowering age at 50% of selected varieties

Varieties	Plant height (cm)				Flowering age at 50% days			
	0% shade	50 % shade	60 % shade	70 % shade	0 % shade	50 % shade	60 % shade	70 % shade
Dawk Pa-yawm	101.83	102.43^{abc}	101.54^{cd}	102.08^{b}	95^{bc}	96^{bc}	96^{bc}	96^{cb}
Nangdum	102.39	103.56^{ab}	103.43^{bc}	102.57^{b}	94^{cd}	95^{c}	95^{cd}	95^{cd}
Dokkam	102.43	104.01^{ab}	104.64^{ab}	103.15^{b}	93^{d}	94^{d}	94^{ed}	94^{e}
Nangchuan	100.76	103.37^{ab}	103.93^{abc}	103.79^{a}	96^{b}	97^{b}	96^{bc}	97^{b}
Lebnok	103.80	105.89^{a}	106.34^{a}	106.48^{a}	95^{bc}	96^{bc}	96^{bc}	96^{bc}
Samduen	104.79	99.31^{c}	99.86^{d}	100.75^{bc}	76^{e}	77^{e}	76^{f}	76^{f}
Lebmuenang	102.80	104.36^{ab}	102.11^{bcd}	101.82^{b}	96^{b}	97^{b}	97^{b}	97^{b}
Pukaotong	105.79	103.58^{ab}	102.69^{bc}	101.89^{b}	93^{bc}	94^{d}	94^{e}	94^{e}
Maepeung	105.93	101.33^{bc}	97.13^{e}	97.95^{c}	77^{e}	78^{e}	77^{f}	77^{f}
Domgatondom	101.25	104.71^{ab}	103.21^{bc}	104.11^{ab}	99^{a}	100^{a}	100^{a}	100^{a}
F-test	ns	*	*	*	*	*	*	*
C.V.%	3.62	2.08	1.57	1.97	0.89	0.85	0.95	0.84

ns = non – significant, * means not followed by the same letter are significantly different at the 5% level of probability as determined by DMRT

Table 2 Harvesting age of the grains and number plant per tiller in selected varieties

Varieties	Harvesting age of the grains (days)				No. plant per tiller			
	0 % shade	50 % shade	60 % shade	70 % shade	0 % shade	50 % shade	60 % shade	70 % shade
Dawk Pa-yawm	129^{c}	130^{c}	130^{b}	131^{b}	5^{ab}	4	2	3$^{/}$
Nangdum	130^{bc}	130^{c}	130^{b}	130^{b}	4^{b}	5	3	2
Dokkam	127^{d}	127^{d}	128^{c}	128^{c}	5^{ab}	4	3	3
Nangchuan	127^{d}	127^{d}	127^{cd}	127^{cd}	6^{a}	4	3	3
Lebnok	127^{d}	127^{d}	127^{cd}	126^{d}	5^{ab}	4	2	2
Samduen	110^{f}	113^{f}	110^{f}	111^{f}	6^{a}	5	3	3
Lebmuenang	131^{b}	131^{b}	130^{b}	131^{b}	5^{ab}	4	3	3
Pukaotong	126^{d}	126^{d}	126^{d}	126^{d}	5^{ab}	4	3	3
Maepeung	115^{e}	116^{e}	115^{e}	115^{e}	5^{ab}	3	2	3
Domgatondom	134^{a}	135^{a}	134^{a}	135^{a}	5^{ab}	4	3	3
F-test	*	*	*	*	*	ns	ns	ns
C.V.%	0.81	0.78	0.80	0.77	21.11	20.10	19.90	23.36

ns = non – significant, * Means not followed by the same letter are significantly different ($p \leq 0.05$) by Duncan's multiple range test

Table 3 Number panicle per tiller and panicle length of selected varieties

Varieties	No. panicle per tiller				Panicle length (cm)			
	0 % shade	50 % shade	60 % shade	70 % shade	0 % shade	50 % shade	60 % shade	70 % shade
Dawk Pa-yawm	3.50^{abc}	3.00^{ab}	1.75^{bc}	1.25	26.17^{c}	28.99^{cd}	25.69^{bc}	25.57^{cd}
Nangdum	3.75^{abc}	2.75^{ab}	2.00^{abc}	1.50	27.92^{b}	30.91^{abc}	27.06^{ab}	26.10^{c}
Dokkam	3.25^{abc}	2.25^{b}	2.00^{abc}	1.25	29.33^{a}	32.95^{a}	28.84^{a}	30.24^{a}
Nangchuan	4.50^{a}	3.25^{ab}	2.50^{ab}	1.75	24.44^{d}	26.16^{e}	24.07^{c}	23.65^{de}
Lebnok	3.00^{bc}	2.75^{ab}	2.00^{abc}	1.50	27.05^{bc}	31.38^{ab}	27.71^{ab}	28.38^{ab}
Samduen	4.25^{ab}	3.75^{a}	3.00^{a}	2.25	27.20^{bc}	26.53^{e}	23.64^{c}	26.48^{bc}
Lebmuenang	3.50^{abc}	3.00^{ab}	2.25^{abc}	1.50	27.70^{b}	32.50^{ab}	26.34^{abc}	27.32^{bc}
Pukaotong	3.50^{abc}	3.50^{ab}	2.25^{ab}	2.00	24.70^{d}	27.24^{de}	23.82^{c}	22.83^{e}
Maepeung	2.75^{b}	2.50^{ab}	1.25^{c}	1.50	23.48^{d}	22.72^{f}	19.06^{d}	20.74^{f}
Domgatondom	2.75^{b}	2.75^{ab}	2.50^{ab}	1.75	27.65^{bc}	30.36^{bc}	27.34^{ab}	27.47^{bc}
F-test	*	*	*	ns	*	*	*	*
C.V.%	25.42	27.67	31.37	36.83	0.55	4.72	7.14	5.26

ns = non – significant, * Means not followed by the same letter are significantly different (p≤ 0.05) by Duncan's multiple range test

Table 4 Number perfect grains per panicle and number of empty grains per panicle in selected varieties

Varieties	No. perfect grains per panicle (grains)				No. of empty grain per panicle (grains)			
	0 % shade	50 % shade	60 % shade	70 % shade	0 % shade	50 % shade	60 % shade	70 % shade
Dawk Pa-yawm	161^{a}	202^{a}	125^{a}	162^{ab}	58^{a}	47^{ab}	35^{ab}	63^{ab}
Nangdum	148^{ab}	206^{a}	126^{a}	129^{abcd}	54^{ab}	40^{ab}	54^{ab}	62^{ab}
Dokkam	153^{ab}	203^{a}	146^{a}	177^{a}	51^{ab}	43^{ab}	46^{ab}	62^{ab}
Nangchuan	129^{abc}	206^{a}	155^{a}	169^{ab}	55^{ab}	50^{ab}	46^{ab}	76^{a}
Lebnok	91^{c}	149^{bc}	127^{a}	149^{abc}	59^{a}	47^{ab}	47^{ab}	65^{ab}
Samduen	106^{bc}	110^{c}	66^{bc}	98^{d}	51^{ab}	50^{ab}	35^{ab}	62^{ab}
Lebmuenang	126^{abc}	189^{ab}	114^{ab}	122^{bcd}	52^{ab}	60^{a}	45^{ab}	60^{ab}
Pukaotong	149^{ab}	190^{ab}	101^{ab}	102^{cd}	70^{a}	47^{ab}	64^{a}	42^{ab}
Maepeung	30^{d}	47^{d}	32^{c}	23^{e}	37^{b}	30^{b}	23^{b}	36^{b}
Domgatondom	91^{c}	219^{a}	113^{ab}	142^{abcd}	54^{ab}	32^{b}	64^{a}	53^{ab}
F-test	*	*	*	*	*	*	*	*
C.V.%	25.04	17.21	29.81	23.01	20.68	37.91	42.20	37.32

* Means not followed by the same letter are significantly different (p≤ 0.05) by Duncan's multiple range test

Table 5 Final yield of selected varieties

Varieties	Yield per acre			
	0 % shade	50 % shade	60 % shade	70 % shade
Dawk Pa-yawm	88.60^{ab}	87.85^{ab}	34.45^{b}	31.20^{ab}
Nangdum	92.44^{ab}	84.78^{ab}	41.45^{ab}	30.80^{a}
Dokkam	82.57^{b}	68.67^{ab}	44.53^{ab}	36.96^{a}
Nangchuan	125.84^{a}	95.80^{ab}	64.32^{a}	45.08^{a}
Lebnok	52.94^{bc}	63.89^{b}	41.56^{ab}	35.52^{a}
Samduen	93.47^{ab}	69.08^{ab}	37.13^{ab}	42.16^{a}
Lebmuenang	88.40^{ab}	98.80^{a}	47.39^{ab}	28.62^{ab}
Pukaotong	85.50^{ab}	98.73^{a}	48.78^{ab}	31.07^{ab}
Maepeung	25.52^{c}	22.88^{c}	8.40c^{b}	9.36^{b}
Domgatondom	54.89^{bc}	96.28^{ab}	50.43^{ab}	39.23^{a}
F-test	*	*	*	*
C.V.%	32.11	26.22	10.62	42.03

* Means not followed by the same letter are significantly different (p≤ 0.05) by Duncan's multiple range test

4 Discussion

Results of the current experiment demonstrated that light intensity levels had little effect on plant height, 50% flowering age, harvesting age, and panicle length at 0%, 50%, 60%, and 70% shading level. Upland rice varieties grown under natural light (0% shading) had higher numbers of tillers and panicles than plants grown under 50%, 60%, and 70% shading. Emmanuel and Mary (2014) and Jonatan et al. (2015) reported that shading reduced the number of plants per tiller and the number of panicles per tiller. Tillering is a genetic characteristic that is also influenced by environmental factors such as low light. Upland rice varieties grown under 50% shade conditions had higher numbers of perfect grains per panicle than rice grown at 0% shading, probably because flowering, seed formation, and ripening stages had no rain, with high average monthly temperatures at 35.69 to 38.42^{o} C (Figure 1) that reduced the number of perfect grains per panicle. Shading conditions also reduced soil moisture loss. In addition, it could reduce the soil and plant temperature during the day (Stigter 1984), with increased numbers of perfect grains per panicle at 50% shading. The ten upland rice varieties responded to shade conditions differently. Among the tested varieties, Lebmuenang, Pukaotong, Damgatondom, and Nangchuan varieties showed good growth and yield under 50% shade, while Pukaotong can be grown under 50 to 60% shade and Samduen can only be grown under 70% shade. Plants that were resistant to shade showed high adaptability to the environment (Muhidin et al. 2013). The upland rice varieties gave diverse yields when grown under shade and suitable cultural practices must be followed for the best results.

Conclusion

Ten varieties of upland rice were grown under diverse shade levels. Lebmuenang, Pukaotong, Damgatondom, and Nangchuan varieties were suited for growth under 50% shade conditions, while Pukaotong, Labnok and Damgatondom varieties were best suited for growth under 60% shade. Samduen was the only variety suitable for cultivation under 70% shade, while Pukaotong grew well under 50 to 60% shaded conditions. The other varieties gave yield at less than 50% compared to upland rice varieties under natural light.

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Conflict of interest

We all the authors hereby declare that there is no conflict of interest among us.

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