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Research Article
Evaluation of the Growth and Yield of Upland Rice Varieties to Drought Stress

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Abstract

Background and Objective: Drought stress affects crop yield by more than 50%. The agronomic characteristics and yielding ability of different upland rice varieties collected in Sabah, Malaysia and to evaluate the response of upland rice varieties to drought stress at the flowering stage. **Materials and Methods:** There were seven upland rice varieties (Tadong, Kondoduvon, Tiga Bulan, Worik, Purak, Lombug, and Kalopak) and one lowland variety as control (Mahsuri) selected for this project. Water stress treatments (by adjusting soil moisture content, SMC) were conducted at the onset of the flowering stage. **Results:** The water stress treatments were T1 (control) (50% SMC), T2 (30% SMC) and T3 (15% SMC). From the application of drought treatments, Kondoduvon-T1 recorded the highest shoot dry mass of 153.57 g. Tadong-T1 recorded the highest 1000-grain weight (34.80 g). Purak-T1 achieved the highest percentage of filled grain 92.08%. The extrapolated yield is significantly and positively correlated with the total number of tillers and most of the yield component parameters. **Conclusion:** Overall, the variety of Purak performed better under drought stress and achieved the highest extrapolated yield and thus suggested to be the best candidate for producing drought tolerant and high-yielding rice variety in the future.

Key words: Upland rice, drought tolerant, rice growth, yield, tolerant

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Drought stress is a long period of water scarcity. It is due to uneven rainfall distribution that may be exacerbated by climate change[1]. This irregular rain distribution is restricting the areas with the potential for planting[2]. The development of drought-tolerant cultivars can be a solution in these drought-prone areas[3]. Yield is essentially the complicated integration of the many rice growing stages, according to Zhang *et al.*[4]. The susceptibility of the plant to water stress during various growth stages is a major factor in the reduction of yield caused by drought. At the flowering stage, rice's physiological characteristics and yield are significantly impacted by drought stress. The decrease in the number of filled spikelets per panicle without a significant decrease in the total number of spikelets per panicle is the key factor contributing to the yield reduction due to water scarcity at the flowering stage[5].

Upland rice is mostly grown by rural communities in Malaysia, particularly in Sabah and Sarawak. Upland rice is cultivated for its appealing qualities, including its smell, colors, sizes and shapes. This rice is frequently regarded as organic food by people who are health conscious[6]. Due to their low grain yields, upland rice varieties have not been widely commercialized. Despite its low yield, upland rice is known for its drought-tolerant properties. It presents a broad adaptation to different soil conditions and climates[7]. When choosing and breeding new plant types with qualities linked to plant yield, several morphological traits are crucial[8,9].

Sabah's demography is dominated by hard hilly terrain to utilize for crops. But upland rice is very versatile and can be planted in these hilly terrains. Despite the multitude amount of upland rice varieties in Sabah and their place in consumers' hearts, little research has been conducted on the yield and growth of upland rice in Sabah.

Hence, the study was conducted to evaluate the agronomic characteristics and yielding ability of upland rice varieties collected in Sabah, Malaysia and to evaluate the responses of upland rice varieties to drought stress in the flowering stage.

MATERIALS AND METHODS

The study was started from May, 2020 to April, 2021. Seven upland rice varieties and one lowland variety from Sabah were used in this study. The upland rice seeds were obtained from Telupid and Ranau, Sabah while the lowland rice seeds were provided by the Department of Agriculture Sabah, Malaysia. The seeds were soaked in 70% alcohol for 2 min before being washed with distilled water for the pot experiment. After that, the seeds were soaked in distilled water and the seeds that floated were discarded while the seeds that sunk were left for 24 hrs before being directly sown into the pot. In this study, one lowland variety was included and planted in aerobic conditions. Prepped seeds were directly planted onto pots with dimensions of 30 cm height×32.5 cm diameter.

Experimental design and data analysis: The seeds were sown on May, 2020 according to a factorial Completely Randomized Design (CRD) with four replicates. There were a total of 96 pots in this study. The distance between pots was 85×65 cm. Each pot was sown with 3 seeds. Each pot was filled with 18 kg of soil mixture composed of Ultisol type of soil, compost and river sand with a 3:1:1 ratio by volume, respectively. All pots were placed randomly in an insect-proof net house at the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, Sandakan Campus, Malaysia. The temperature ranges from 26 to 32°C with relative humidity of 50-60%. The yield components, rice yield and growth characteristics were determined using the Standard Evaluation System for the Rice method at maturity[10].

Statistical analysis: The data obtained were analyzed using Statistical Analysis System (SAS). The SAS® University Edition software was used to perform a Two-way Analysis of Variance (ANOVA) on the gathered data[11]. When ANOVA revealed significant treatment effects in this study, the Least Significant Difference (LSD) test was performed to compare between means at a 0.05 level of probability. Using Pearson's correlation coefficients, the correlation between vegetative growth parameters, yield components and drought levels as well as between yields in drought treatments were evaluated.

Drought stress treatment: When a rice plant reaches the flowering period, the drought-stress treatment was started (Table 1). The drought stress was induced by adjusting the soil moisture content. There were three levels of soil moisture content (SMC) which were 50% (control treatment), 30% and 15%. The 50% SMC was chosen as the control treatment because is the maximum water field capacity of the soil. The SMC was maintained by watering with fixed water volume and by observing the soil moisture level using a portable Field Scout Soil Sensor Reader. On the 20th day of drought stress treatment commencement, leaf and root samples were collected and analyzed for biochemical analysis. The drought treatment was maintained until harvesting of the panicle.

Table 1: Drought treatment commencement

Variety	Drought treatment commencement (DAS)
Mahsuri (lowland)	105
Tadong	71
Kondoduvon	107
Tiga Bulan	100
Worik	114
Purak	81
Lombug	117
Kalopak	82

Table 2: Harvesting day of rice varieties

Variety	Harvesting day (DAS)
Mahsuri (lowland)	140
Tadong	108
Kondoduvon	144
Tiga Bulan	135
Worik	141
Purak	128
Lombug	154
Kalopak	111

Parameters: The vegetative growth parameters and yield components were recorded in this study. The vegetative growth parameters were plant height, leaf area, number of tillers per plant and dry weight of shoot. Data for plant height were taken every 10 days until harvesting. Recording of the leaf area and the number of tillers per plant were done on the 20th day after the commencement of drought treatment. Plant height was measured from the plant's base to the top of the latest spikelet on the panicle, excluding the awn. The leaf length and leaf width were taken using a measuring tape. The leaf area was calculated using the data for the width of the leaf and length of the leaf.

In addition, the yield components were the percentage of the productive tiller, panicle length, total number of grains, percentage of filled grains, 1000-grain weight, yield per plant, as well as extrapolated yield. The data for yield components were taken at harvest. Productive tillers were counted and recorded as a percentage of productive tillers (%) on a single plant. The length of the panicle, excluding the awn, was measured from the base of the lowest spikelet to the tip of the latest spikelet. The number of grains per panicle was counted after harvesting and the percentage of filled grains was calculated from the filled grains. Using a Mettler Toledo AB204-S analytical balance, the constant 1000-grain weight was determined after the samples were dried in a 70°C oven for three days. The extrapolated yield was calculated according to Patel *et al*.[12]. The yield per plant was calculated from the weight of the total number of filled grains per plant. The harvesting day for each variety was shown in Table 2.

RESULTS AND DISCUSSION

Effects of drought levels and rice varieties on vegetative growth of rice

Plant height: There was no significant effect between drought levels and rice varieties ($p>0.05$) (Table 3). However, there was a significant difference in the plant height of the rice varieties ($p<0.05$) during the harvesting stage. The plant height of rice varieties ranged from 127.83 to 167.42 cm. Tadong was recorded as the tallest variety at 167.42 cm while the varieties of Mahsuri, Kondoduvon, Tiga Bulan, Worik and Purak are grouped with the lowest plant height. All of the studied varieties are categorized as tall varieties according to the classification by IRRI[10]. The genetics of the cultivar largely determine the plant height of rice, although environmental conditions can have an impact[13]. Greater plant heights are typically associated with larger total plant sizes, increased light absorption and accelerated transpiration of water. This results in lower plant water status, more sterile spikelets[14] and higher leaf death scores[15].

Number of tillers per plant: From Table 3, the rice varieties showed a significant difference ($p<0.05$) in the number of tillers produced during the harvesting stage. The control variety of Mahsuri recorded the highest number of tillers (29) as compared to the varieties of Tadong, Kondoduvon, Tiga Bulan, Worik, Purak, Lombug and Kalopak. Rice tillering ability is linked to the number of panicles and thus yields[16]. Tillering, whether excessive or insufficient, is detrimental to high yield. The varietal significant difference in tillers was due to their genetic make-up and a similar finding was reported by Hossain *et al*.[17].

Leaf area of flag leaf: There was no interaction between rice varieties and drought levels on the leaf area of the flag leaf ($p>0.05$) (Table 3). However, the rice varieties significantly differed ($p<0.05$) in leaf area regardless of the drought levels. The variety of Kalopak recorded the largest leaf area (73.25 cm^2) compared to the other varieties. Meanwhile, there was a significant effect of drought stress levels ($p<0.05$) on the leaf area. The control treatment, 50% SMC (Treatment 1, T1) produced the largest leaf (53.4 cm^2) as compared to 30% SMC (Treatment 2, T2, 48.27 cm^2) and 15% SMC (Treatment 3, T3, 44.55 cm^2). A sufficient amount of leaf area is necessary for photosynthesis, which is the main factor driving plant growth. Even though the flag leaf's photosynthetic rate and capacity may be the main sources of crop yield, they are susceptible to drought stress[18]. Reduced leaf area due to water stress will result in decreased photosynthesis, which lowers crop yield[19]. The declining leaf area from Treatment 1 (T1) to Treatment 3 (T3) may be due to an effort to conserve water under water-deficit conditions. Although having a smaller leaf area encourages using less water, it could also result in reduced grain yield[20].

Day to maturity: From Table 3, the rice varieties significantly differed ($p<0.05$) on the day to maturity. The varieties of Tadong and Kalopak recorded the shortest day to maturity while the Lombug variety took the longest day to maturity (153.75 DAS). The duration of rice maturity is varietal and genetically controlled[21]. Low water availability during the vegetative phase, on the other hand, reduces the growth duration of rice. When plants are stressed by drought, they take a longer time to reach maturity, which corresponds to a delay in flowering[22]. Contrary, research by Ihsan *et al.*[23] showed that stressed plants reach maturity sooner than non-stressed plants.

Dry weight of shoot: There was significant interaction ($p<0.05$) (Table 3) in the rice varieties and drought levels on the dry weight of the shoot. Kondoduvon variety in the control treatment, T1 recorded the highest dry weight of the shoot (153.57 g) whereas Kalopak-T3 (22.36 g) produced the lowest dry weight of the shoot among these treatments. There is a declining trend in the dry weight of shoots from T1 to T3 in all studied varieties. Cell growth and expansion are greatly suppressed under drought stress due to the low turgor pressure. This can be seen in the 74.58 g difference between the highest dry weight, Kondoduvon-T1 and the lowest dry weight, Kalopak-T3. However, osmotic regulation can accommodate plant growth which aids the survival of plants under severe drought conditions by the maintenance of cell turgor[24]. Drought affects both the grain and dry weight of rice. A study done by Zhang *et al.*[4] showed that drought significantly decreased the dry weight of rice grown in the field by up to 40%. The decrease in dry weight is mainly due to a decrease in grain yield and secondly in plant height.

Effects of drought levels and rice varieties on the yield component of rice

Panicle length: There was no interaction between rice varieties and drought levels on the panicle length (Table 4). However, rice varieties significantly differed ($p<0.05$) in panicle length. Tadong variety has the highest mean panicle length (32.25 cm) while the control variety, Mahsuri as well as the varieties of Kondoduvon and Worik showed the lowest mean panicle length. Different drought levels also had a significant effect on the panicle length ($p<0.05$) (Table 4). The control treatment, 50% SMC (Treatment 1, T1) and 30% SMC (Treatment 2, T2) produced the highest mean of 26.84 cm and 26.37 cm, respectively. One characteristic of panicle architecture that is frequently measured as a trait connected to yield is the length of the panicle[25]. The development of panicles and spikelet morphogenesis is a key element since it directly affects rice yield. The heritability of panicle length was both high and moderate, suggesting that genetic variables influenced phenotypes more so than environmental ones[26]. Despite the genetic factors, panicle exertion that results from internode elongation is a broad growth process. Panicle development is sensitive to water stress and it is closely related to turgor-mediated processes. Early stages of reproduction experience a reduction in leaf and spikelet water potential underwater stress[14]. In the floral organs, this restricts cell growth and metabolism of carbohydrates[27].

1000-grain weight: From Table 4, there was an interaction between the rice varieties and drought levels on 1000-grain weight ($p<0.05$). Tadong and Purak varieties at 50% SMC recorded the highest 1000-grain weight whereas the Mahsuri variety at 15% SMC (Mahsuri-T3) (12.37 g) showed the lowest 1000-grain weight among these treatments. The 1000-grain weight significantly decreased with increasing drought levels. One of the yield factors that contribute to yield decline in a drought environment is grain weight[24]. Drought stress can influence grain development by affecting the filling degree, spikelet fertility, or the size and maximal weight of the filled grain. In this study, there is a significant reduction in 1000-grain weight across all varieties with increasing drought levels. The weight of the grain is mostly governed by the genetically determined seed width and length, although drought stress during the flowering phase impairs the process of filling the grain, making the grain lighter[28]. A lower final grain weight results from reduced grain filling time and rate caused by drought stress[29].

Percentage of filled grain: The analysis showed that there was a significant interaction between the different rice varieties and different drought levels on the percentage of filled grain ($p<0.01$) (Table 4). The Purak variety in the control treatment, 50% SMC (Purak-T1) recorded the highest percentage of filled grain (92.08%) whereas Lombug-T3 (4.16%) was the lowest percentage of filled grain among these treatments. Grain yields are significantly reduced as a result of a significant negative impact on meiosis and anthesis, which has a direct impact on grain number[30]. The results of this study also revealed that the percentage of filled grain was

Table 3: Effect of variety and drought on the vegetative parameters recorded in this study

		Vegetative parameters				
Effect	Variety	PH	TT	LA	TD	DW
Variety (V)		**	**	**	**	ns
	Mahsuri (lowland)	128.5[d]	29[a]	32.91[e]	139.75[b]	69.45
	Tadong	167.42[a]	6.58[d]	59.32[b]	107.5[e]	41.06
	Kondoduvon	134.5[cd]	23.00[b]	43.5[cd]	143.5[b]	109.57
	Tiga Bulan	129.42[d]	15.92[c]	46.55[cd]	133.17[c]	61.73
	Worik	133.42[cd]	15.33[c]	35.69[de]	140.50[b]	75.17
	Purak	127.83[d]	21.67[b]	54.95[b]	128.00[d]	100.16
	Lombug	137.67[c]	11.67[c]	43.75[cd]	153.75[a]	75.45
	Kalopak	148.58[b]	5.42[d]	73.25[a]	110.83[e]	28.84
Drought (D)		ns	ns	*	ns	ns
	T1 (control)		16.22	53.4[a]	133.00	86.93
	T2		16.16	48.27[b]	131.69	65.86
	T3		15.84	44.55[b]	131.69	57.75
V*D		ns	ns	ns	ns	*

ns: Non-significant, *Significance level at p<0.05, **Significance level at p<0.01, different letters indicate significant differences between means of four replications according to the LSD test (probability level of 5%), PH: Plant height, TT: Total number of tillers, LA: Leaf area, TD: Day to maturity, DW: Dry weight of shoot, T1: 50% soil moisture content, T2: 30% soil moisture content and T3: 15% soil moisture content

Table 4: Effect of variety and drought on the yield components in this study

		Yield components						
Effect	Variety	PL	PT	GW	FG	GP	YPP	EY
Variety (V)		**	ns	ns	**	**	**	**
	Mahsuri (lowland)	21.50[e]	89.5	33.42	88.1	132.71[bc]	36.81[b]	5.38[b]
	Tadong	32.25[a]	79.48	13.06	82.12	151.58[b]	22.88[c]	3.18[c]
	Kondoduvon	21.33[e]	79.63	21.41	37.85	98.26[d]	16.2[c]	2.28[c]
	Tiga Bulan	24.03[d]	77.94	22.11	70.21	121.3[cd]	24.12[c]	3.40[c]
	Worik	22.21[de]	82.86	20.42	52.49	131.52[bc]	18.11[c]	2.63[c]
	Purak	29.51[b]	86.46	31.99	74.94	153.76[b]	60.06[a]	8.46[a]
	Lombug	26.93[c]	94.43	22.84	30.6	149.42[b]	15.83[c]	2.23[c]
	Kalopak	30.76[b]	92.78	24.22	66.09	224.67[a]	18.37[c]	2.59[c]
Drought (D)		*	ns	*	**	*	**	**
	T1 (control)	26.87[a]	93.39	25.59	76.72	157.58[a]	39.75[a]	5.31[a]
	T2	26.37[ab]	81.69	23.53	61.88	139.44[b]	22.08[b]	3.46[b]
	T3	24.95[b]	83.94	21.92	49.79	139.19[b]	17.82[b]	2.53[c]
V*D		ns	ns	*	**	ns	ns	ns

ns: Non-significant, *Confidence level at p<0.05, **Confidence level at p<0.01, Different letters indicate significant differences between means of four replications according to the LSD test (probability level of 5%), PL: Panicle length, PT: Total productive tiller, GW: 1000-grain weight, FG: Percentage of filled grain, GP: Grain per panicle, YPP: Yield per plant, EY: Extrapolated yield, T1: 50% soil moisture content, T2: 30% soil moisture content and T3: 15% soil moisture content

significantly impacted by drought stress during the flowering stage, with a reduction of 31.15% in Purak-T1 and Purak-T3. Grain yield is reduced more drastically as a result of water stress during the flowering stage, which lowers the fertile panicles and the percentage of filled grains[31].

Total grain per panicle: From Table 4, the analysis showed that different rice varieties significantly differed (p<0.05) in total grain per panicle. The Kalopak variety recorded the highest mean of total grain per panicle (224.67). There was a significant difference in drought stress (p<0.05) in the total grain per panicle. The control treatment, 50% SMC (Treatment 1) produced the highest mean of total grain per panicle (157.58) as compared to 30% SMC (Treatment 2) (139.44) and 15% SMC (Treatment 3) (139.19). The control variety, Mahsuri and the variety of Tiga Bulan both significantly have the lowest total grain per panicle. However, there was no significant interaction between the different rice varieties and different drought levels on the total grain per panicle (p>0.05). The result of this study showed that the spikelets per panicle of the Mahsuri variety are lower when planted in aerobic conditions. This might be due to the shift in soil conditions that affect nutrient availability to the crop[32]. The interaction of a genotype and its environment determines the final spikelet number[33]. The rachis branch's development determines the total number of spikelets produced by a panicle[34].

Yield per plant: There was no interaction between the different rice varieties and different drought levels on the yield per plant (p>0.05) (Table 4). However, different rice varieties

Table 5: Correlation matrix between studied traits in rice varieties under drought stress

Parameter	1	2	3	4	5	6	7	8	9	10	11	12
TPT	-											
TT	-0.231*	-										
TD	0.046	0.395**	-									
PL	0.142	-0.551**	-0.557**	-								
FG	0.01	0.015	-0.468**	0.355**	-							
GP	0.250*	-0.505**	-0.417**	0.672**	0.285**	-						
GW	-0.014	-0.410**	-0.490**	0.609**	0.272**	0.204*	-					
EY	0.145	0.375**	-0.11	0.258*	0.630**	0.237*	0.276**	-				
LA	0.141	-0.449**	-0.574**	0.544**	0.237*	0.468**	0.507**	0.102	-			
DW	-0.031	0.438**	0.489**	-0.265**	-0.059	-0.300*	-0.01	0.377**	-0.252*	-		
PH	0.031	-0.517**	-0.572**	0.500**	0.185	0.287**	0.400**	-0.205*	0.394**	-0.434**	-	
YPP	0.145	0.375**	-0.109	0.258**	0.630**	0.237*	0.276**	1.000**	0.102	0.377**	-0.205*	-

*Significant (p<0.05), **Significant (p<0.01), TPT: Total productive tiller, TT: Total tiller, TD: Day to maturity, PL: Panicle length, FG: Percentage of filled grain, GP: Grain per panicle, GW: 1000-grain weight, EY: Extrapolated yield, LA: Leaf area, DW: Dry weight of shoot, PH: Plant height and YPP: Grain yield per plant

significantly differed ($p<0.05$) in yield per plant. The variety of Purak recorded the highest yield per plant (60.06 g), while the varieties of Tadong, Kondoduvon, Tiga Bulan, Worik, Lombug and Kalopak recorded the lowest yield per plant. Different drought levels also had a significant effect on the yield per plant ($p<0.05$). When exposed to the control treatment (T1), the rice plants produced a significantly highest yield per plant of 39.75 g. According to Efisue *et al.*[35] several agronomic characteristics, including days to maturity, heading days, grain filling duration, number of filled grains per panicle, panicle length, plant height and number of productive tillers, are used to predict the grain production of a rice plant. The tillering ability of a rice plant is related closely to the panicle number. The low number of tillers results in a low number of panicles, but excess tillers result in high tiller mortality, the small size of panicles and poor filling of grain, reducing the rice plant's grain yield. Ogunbayo *et al.*[36] reported that the traits attributing grain yield per plant such as the total number of tillers and panicle length are highly influenced by genetics.

Extrapolated yield: Yield is the most important indicator of a crop. The analysis showed that the rice varieties significantly differed ($p<0.05$) (Table 4) on the extrapolated yield. The Purak variety produced the highest mean of extrapolated yield (8.46 tons ha^{-1}), there was a significant effect of drought stress ($p<0.05$) on the extrapolated yield. The control treatment (T1) significantly produced the highest mean of 5.31 tons ha^{-1} as compared to Treatment 2 (3.46 tons ha^{-1}) and Treatment 3 produced the lowest mean of 2.53 tons ha^{-1}. There was a difference of 2.78 tons ha^{-1} between Treatment 1 and Treatment 3. The number of spikelets per panicle, percentage of filled grain per panicle, number of panicles per area and 1000-grain weight are the yield components that determine the extrapolated yield of each variety[37]. The extrapolated yield of the rice varieties had been greatly impacted by the drought treatment, which had a substantial impact on the number of 1000-grain weight, spikelets per panicle and percentage of filled grains per panicle.

Correlation analysis of vegetative characteristics and yield components: The result of the correlation analysis under drought conditions showed that the vegetative characteristics and yield components had a significant correlation (Table 5). In this drought study, a positive and significant correlation was observed between extrapolated yield and yield per plant ($r = 1.00$, $p<0.01$), total tiller ($r = 0.37$, $p<0.01$), panicle length ($r = 0.26$, $p<0.05$), total grain per panicle ($r = 0.24$, $p<0.05$), percentage of filled grain ($r = 0.63$, $p<0.01$), 1000-grain weight ($r = 0.28$, $p<0.01$) and dry weight of shoot ($r = 0.38$, $p<0.01$). However, a negative and significant correlation was observed between extrapolated yield and plant height ($r = -0.21$, $p<0.05$).

Farmers can cultivate the Purak variety in soil moisture as low as 15% and still achieve acceptable production. Production of drought-resistant rice variety, such as Purak variety can contribute to global food security by ensuring stable yields in regions prone to water scarcity. It reduces the risk of crop failure and helps maintain a consistent rice supply even during drought conditions. In addition, drought-resistant rice variety can provide economic benefits to farmers, as it minimizes yield losses and ensures a steady income even in drought-prone areas. It can also reduce the need for expensive irrigation practices, saving farmers money in the long run. By reducing the water requirements for rice cultivation, drought-resistant varieties can contribute to water conservation. It reduces the strain on freshwater resources and promotes sustainable agriculture practices, thereby minimizing the environmental impact of rice production.

Despite the findings of this research, additional studies using more replicates and planting cycles of rice should be carried out to assess the impacts of drought stress on the development and production of upland varieties, particularly the Purak variety. Continued investment in research and development is essential to enhance the drought tolerance of rice. Scientists should focus on identifying key genes and traits associated with drought resistance and use advanced breeding techniques, such as marker-assisted selection and genetic engineering, to develop improved varieties. On the other hand, farmers need access to information and training on the cultivation and management of drought-resistant rice. Extension services and agricultural institutions should organize awareness programs, field demonstrations and workshops to educate farmers about the benefits and best practices of using drought-resistant varieties.

CONCLUSION

Some of the Sabah traditional upland rice varieties have the potential to be cultivated because they can contribute a stable yield under different drought conditions. Data obtained in this experiment demonstrated that different rice varieties showed a significant difference in most parameters, meanwhile, drought levels only showed significance in leaf area, panicle length, total grain per panicle and extrapolated yield. Purak variety under control treatment (50% SMC) recorded the highest percentage of the filled grain at 92.08% and exhibited the best tolerance to drought when under 50, 30 and 15% SMC.

SIGNIFICANCE STATEMENT

This research exposed an optimal drought tolerance level for upland rice in rice production systems that researchers have yet to investigate. As a result, a new drought-tolerant and high-yielding rice variety could be developed in the future breeding program.

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