GRAIN CHARACTERISTICS AS MORPHOLOGICAL PREDICTOR FOR DROUGHT TOLERANCE IN LOCAL UPLAND RICE CULTIVARS FROM JAMBI PROVINCE, INDONESIA

Zulkarnain ZULKARNAIN[*,**], Eliyanti ELIYANTI[*], Budiyati ICHWAN[*], Sosiawan NUSIFERA[*], Yulia ALIA[*]

[*] *University of Jambi, Faculty of Agriculture, Department of Agroecotechnology, Kampus Pinang Masak, Jambi, Indonesia.*
[**] *Center of Excellence for Biodiversity and Land-use Transformation Systems (BLasTS), Jambi, Indonesia.*
Corresponding author: Zulkarnain Zulkarnain, University of Jambi, Faculty of Agriculture, Department of Agroecotechnology. Kampus Pinang Masak, Jl. Raya Jambi – Muara Bulian KM 15, Jambi, Indonesia 36361, phone: +62812747897, email: dr.zulkarnain@yahoo.com

Abstract. The development of drought-tolerant upland rice requires a source of resistance genes, some of which can be obtained from local cultivars that have adapted to specific environmental conditions. Jambi is one of the provinces in Indonesia rich in local upland rice diversity. These varieties, through a selection process, have the potential to be developed as tolerant cultivars, either directly or as cross-bred parents. This study aimed to explore the genetic resources of local upland rice cultivars in Jambi Province, Indonesia, and identify and select local upland rice genotypes with drought-tolerant traits based on their grain characteristics. Exploration was carried out in several upland rice cultivation centers in Sarolangun and Merangin Regencies from February to September 2025. Sample plants were taken from field, then evaluated based on panicle and grain morphology. Observations were made on: lemma and palea colour, hairs on lemma and palea, sterile lemma colour, sterile lemma length, grain tip colour, grain tip hairs, grain tip hairs, hair length, seed length, seed width, length:width ratio, and seed thickness. Cluster analysis by the Unweighted Pair Group Method Arithmetic (UPGMA) method using the Numerical Taxonomy System (NTSYS) Program showed the presence of 5 accession groups at a 50% similarity level. This indicates broad differences in genetic background as a result of adaptation to environmental conditions in the evolutionary process. Cultivars in the same group showed a high level of genetic similarity, while those in different groups showed genetic differences. Our study showed that the qualitative characteristics of grain: the colour of lemma and palea, the colour of sterile lemma, the colour of apiculus, and the presence of hairs on the grain, related to abiotic stress-tolerant. This indicates their potential use to develop efficient protocol for selection of drought-tolerant rice cultivars. The results of this exploration have great potential for further development through breeding programs and conservation efforts for local Jambi upland rice cultivars.

Keywords: dryland rice; food crop; *Oryza sativa*; plant breeding.

INTRODUCTION

Food crop cultivation, including rice, currently faces serious challenges due to climate change, which alters rainfall patterns. Shifting in rainfall pattern and water holding capacity around the rhizosphere [25] had resulted in increased intensity of droughts, which directly affected dryland agricultural systems. Rice with shallow root systems are susceptible to drought stress, which in turn reduces productivity. One of solutions to this problem is to develop superior drought-tolerant cultivars.

Developing superior drought-tolerant upland rice cultivars based on local cultivars is becoming important, given the wide variation in environmental conditions in potential dryland areas. Domingo *et al.* [6] suggested that one of the primary goals of rice breeding was to develop drought-adaptive varieties by utilizing parents with tolerance traits. Because they have long been cultivated in marginal environments, local varieties are likely to have adapted to these conditions and serve as potential sources of drought-tolerant parents.

The success of breeding programs depends heavily on the availability of broad genetic diversity within the population, as this determines the effectiveness of selection and the genetic progress that can be achieved. Local cultivars are a strategic source of genetic diversity for developing superior varieties [4]. The wide variation in characteristics of local rice is thought to be the result of its wide geographic distribution and long history of cultivation [24]. Study by Domingo *et al.* [6] on nine local upland rice cultivars from Bukidnon, the Philippines, demonstrated genetic variation associated with genes controlling drought tolerance traits. Meanwhile, Samudin [28] found three of twelve local upland rice cultivars from Central Sulawesi, Indonesia, to be drought tolerant. In addition, Lanna *et al.* [16] identified five accessions with the best yield performance under drought conditions from 25 upland rice accessions from Brazil.

Jambi Province is one of Indonesia's provinces rich in local upland rice cultivars with potential as sources of drought-tolerant genes. However, many of these potential cultivars have not yet been identified and characterized. Therefore, exploration and characterization are critical efforts to seek prospective upland rice germplasms from Jambi for future use in rice breeding program.

Exploration is the activity of searching, collecting, and identifying specific local varieties in a specific area. This can be done in production areas, traditional production areas, isolated areas, agricultural areas on mountain slopes, remote islands, customary areas, areas with traditional agricultural systems, areas where residents utilize agricultural products as a staple food, areas endemic to pests and diseases, and areas of old and new settlements [7]. Characterization is a follow-up activity to exploration and collection activities aimed at evaluating the characteristics of the germplasm of local varieties obtained [31]. Among the traits evaluated are morpho-agronomic, physiological, and molecular.

To meet future food demands, increased efforts to develop drought-tolerant crops and the use of economical and beneficial agricultural practices will be crucial [30]. Therefore, this study aimed to explore local Jambi upland rice cultivars cultivated in several

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locations in Sarolangun and Merangin Regencies, Jambi Province, Indonesia, and to investigate the drought-tolerant potential of upland rice cultivars resulting from the exploration using grain characteristics as morphological predictors. The results of this study are expected to provide valuable contribution in developing efficient protocol for selection of drought-tolerant upland rice cultivars.

MATERIAL AND METHODS

The exploration of local Jambi upland rice cultivars was conducted in Sarolangun and Merangin Regencies, Jambi Province, Indonesia. Seven sub-districts were explored, i.e. Batin VIII, Pauh, Batang Asai, Cermin Nan Gedang, Mandiangin, Sarolangun, and Muaro Siau. These sub-districts were known as main locations for local upland rice cultivation. Sampling locations were selected based on information gathered from community leaders, farmers, extension workers, and regional agricultural office. Information on local cultivar names was obtained from farmers at the sampling sites. Five panicle samples that met harvest criteria (maturation phase) were randomly selected from one clump of sample plants in the field for each cultivar. The panicles were then taken to the laboratory and grown in research farm for observation.

Initial diversity evaluation was conducted on several grain morphological traits based on the Rice Standard Evaluation System [9]. Observation was made on grain morphological traits, both qualitative and quantitative. Qualitative characters consist of lemma and palea colour, hair on the lemma and palea, sterile lemma colour, sterile lemma length, grain tip colour (apiculus), grain tip hair, grain tip hair colour, and grain shape. While quantitative characters consist of hair length, grain length, grain width, grain thickness, and grain length:width ratio. Observations of grain morphological characteristics were conducted on 10 full individual grains randomly taken from 5 sample panicles. Observations of qualitative characteristics related to colour were assisted by the Munsell Plant Tissue Colour Chart.

The morphological characters of the grain were analysed using NTSYS (Numerical Taxonomy System), which produces a dendrogram output, illustrating the close relationship among the evaluated cultivars.

RESULTS

Exploration conducted in six sub-districts within Sarolangun Regency and one sub-district in Merangin Regency resulted in 48 local upland rice cultivars. The highest number of cultivars (18 cultivars) was found in Batin XVIII Sub-district, Sarolangun Regency. While the lowest number (2 cultivars) was found in Muara Siau Sub-district, Merangin Regency (Table 1).

The following are the results of characterization performed on the grain characteristics of all cultivars obtained from the exploration, including qualitative (Table 2) and quantitative (Table 3) traits.

Table 1. List of local upland rice cultivars from exploration in Sarolangun and Merangin Regencies, Jambi Province, Indonesia.

No	Accession Code	Local Name	Origin		
			Village	Sub-district	Regency
1	SRL-BP-001	Bakang	Tanjung	Batin VIII	Sarolangun
2	SRL-BP-002	Godang	Tanjung	Batin VIII	Sarolangun
3	SRL-BP-003	Endek	Tanjung	Batin VIII	Sarolangun
4	SRL-BP-004	Harum	Tanjung	Batin VIII	Sarolangun
5	SRL-BP-005	Bungo Kelapo	Tanjung	Batin VIII	Sarolangun
6	SRL-BP-006	Air Mas	Tanjung	Batin VIII	Sarolangun
7	SRL-BP-007	Ekor Kuda	Tanjung	Batin VIII	Sarolangun
8	SRL-BP-008	Padi Kubu	Tanjung	Batin VIII	Sarolangun
9	SRL-BP-009	Bungo Duku	Tanjung	Batin VIII	Sarolangun
10	SRL-BP-010	Kasah	Tanjung	Batin VIII	Sarolangun
11	SRL-BP-011	Silang	Tanjung	Batin VIII	Sarolangun
12	SRL-BP-012	Ruyung	Tanjung	Batin VIII	Sarolangun
13	SRL-BP-013	Seni Kuning	Tanjung	Batin VIII	Sarolangun
14	SRL-BP-014	Perak Putih	Tanjung	Batin VIII	Sarolangun
15	SRL-BP-015	Seni Ruyung	Tanjung	Batin VIII	Sarolangun
16	SRL-BP-016	Rejang	Tanjung	Batin VIII	Sarolangun
17	SRL-BP-017	Cenano	Tanjung	Batin VIII	Sarolangun
18	SRL-BP-018	Bungo Kelapo Kuning	Tanjung	Batin VIII	Sarolangun
19	SRL-BP-019	Perak	Pangidaran	Pauh	Sarolangun
20	SRL-BP-020	Seni Gedang	Pangidaran	Pauh	Sarolangun
21	SRL-BP-021	Payo	Pangidaran	Pauh	Sarolangun
22	SRL-BP-022	Jambi-1	Sekeladi	Batang Asai	Sarolangun
23	SRL-BP-023	Kecik Kancil	Sekeladi	Batang Asai	Sarolangun
24	SRL-BP-024	Rambai Kuaw	Sekeladi	Batang Asai	Sarolangun
25	SRL-BP-025	Putih	Sekeladi	Batang Asai	Sarolangun
26	SRL-BP-026	Utal	Sekeladi	Batang Asai	Sarolangun
27	SRL-BP-027	Kecik Seni	Sekeladi	Batang Asai	Sarolangun

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No	Accession Code	Local Name	Origin		
			Village	Sub-district	Regency
28	SRL-BP-028	Temiang Merindu	Sekeladi	Batang Asai	Sarolangun
29	SRL-BP-029	Bungo Belimbing	Sekamis	Cermin Nan Gedang	Sarolangun
30	SRL-BP-030	Alui	Sekamis	Cermin Nan Gedang	Sarolangun
31	SRL-BP-031	Gedang Putih	Sekamis	Cermin Nan Gedang	Sarolangun
32	SRL-BP-032	Halus	Taman Dewa	Mandiangin	Sarolangun
33	SRL-BP-033	Terong	Penarun	Sarolangun	Sarolangun
34	SRL-BP-034	Seni Kuku Balam	Penarun	Sarolangun	Sarolangun
35	SRL-BP-035	Seni Ekor Kuda	Penarun	Sarolangun	Sarolangun
36	SRL-BP-036	Seni Kabut	Penarun	Sarolangun	Sarolangun
37	SRL-BP-037	Tampang Bedaro	Penarun	Sarolangun	Sarolangun
38	SRL-BP-038	Empat Bulan	Penarun	Sarolangun	Sarolangun
39	SRL-BP-039	Mayang Rindu	Penarun	Sarolangun	Sarolangun
40	SRL-BP-040	Bungo Cempako	Lidung	Sarolangun	Sarolangun
41	SRL-BP-041	Kabut	Lidung	Sarolangun	Sarolangun
42	SRL-BP-042	Seni	Lidung	Sarolangun	Sarolangun
43	SRL-BP-043	Bungo Buluh	Lidung	Sarolangun	Sarolangun
44	SRL-BP-044	Buah Bernai	Lidung	Sarolangun	Sarolangun
45	SRL-BP-045	Bujang	Lidung	Sarolangun	Sarolangun
46	SRL-BP-046	Jambi-2	Lidung	Sarolangun	Sarolangun
47	MRG-BP-047	Padi Tanjung	Teluk Sikumbang	Muara Siau	Merangin
48	MRG-BP-048	Padi Nek Alui	Teluk Sikumbang	Muara Siau	Merangin

Table 2. Diversity of qualitative grain characteristics of local upland rice cultivars from exploration in Sarolangun and Merangin Regencies, Jambi Province, Indonesia.

Cultivars	Characteristics							
	Lemma and Palea Colour	Lemma and Palea Pubescence	Sterile Lemma Colour	Lemma Sterile Length	Apiculus Color	Awn	Awn Colour	Grain Shape
Bakang	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Godang	Brown	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Endek	Purple spots on straw	Short hair	Straw	Long	Straw	Absent	Awnless	Medium
Harum	Brown	Short hair	Red	Long	Purple	Absent	Awnless	Slender
Bungo Kelapo	Brown	Short hair	Straw	Long	Straw	Absent	Awnless	Slender
Air mas	Brown	Short hair	Straw	Long	White	Absent	Awnless	Slender
Ekor Kuda	Straw	Hairs on upper portion	Gold	Long	Red apex	Absent	Awnless	Slender
Kubu	Brown	Short hair	Gold	Medium	Purple apex	Absent	Awnless	Bold
Bungo Duku	Purple spots on straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Kasah	Straw	Short hair	Straw	Long	Straw	Long and partly awned	Straw	Slender
Silang	Brown	Short hair	Straw	Long	Straw	Absent	Awnless	Slender
Ruyung	Brown spots on straw	Long hairs	Gold	Long	Purple	Absent	Awnless	Medium
Seni Kuning	Brown	Short hair	Straw	Medium	Brown	Absent	Awnless	Medium
Perak Putih	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Seni Ruyung	Brown spots on straw	Short hair	Gold	Long	Brown	Absent	Awnless	Slender
Rejang	Brown	Short hair	Straw	Medium	Purple apex	Absent	Awnless	Medium
Cenano	Straw	Hairs on upper portion	Straw	Long	Straw	Absent	Awnless	Medium
Bungo Kelapo Kuning	Straw	Short hair	Straw	Medium	Purple	Absent	Awnless	Medium
Perak	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Payo	Straw	Short hair	Straw	Long	Straw	Absent	Awnless	Medium
Jambi-1	Straw	Short hair	Gold	Medium	Brown	Absent	Awnless	Medium
Kecik Kancil	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Rambai Kuaw	Straw	Short hair	Gold	Medium	Purple apex	Absent	Awnless	Slender
Putih	White	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Utal	Straw	Hairs on upper portion	Red	Medium	Purple apex	Absent	Awnless	Medium
Kecik Seni	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Temiang Merindu	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender

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Cultivars	Characteristics							
	Lemma and Palea Colour	Lemma and Palea Pubescence	Sterile Lemma Colour	Lemma Sterile Length	Apiculus Color	Awn	Awn Colour	Grain Shape
Bungo Belimbing	Brown spots on straw	Short hair	Straw	Long	Brown	Absent	Awnless	Slender
Alui	Straw	Short hair	Straw	Long	Straw	Absent	Awnless	Medium
Gedang Putih	Straw	Short hair	Gold	Medium	Purple	Absent	Awnless	Slender
Halus	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Terong	Brown	Short hair	Straw	Medium	Straw	Absent	Awnless	Bold
Seni Kuku Balam	Straw	Short hair	Gold	Long	Straw	Absent	Awnless	Slender
Seni Ekor Kuda	Straw	Short hair	Gold	Medium	Purple apex	Absent	Awnless	Slender
Seni Kabut	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Empat Bulan	Gold and gold furrows on straw background	Short hair	Straw	Long	Straw	Absent	Awnless	Medium
Mayang Rindu	Brown	Hairs on upper portion	Purple	Medium	Purple apex	Absent	Awnless	Slender
Bungo Cempako	Gold and gold furrows on straw background	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Kabut	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Seni	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Bungo Buluh	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Buah Bernai	Straw	Glabrous	Red	Medium	Brown	Short and fully awn	Black	Bold
Bujang	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Medium
Jambi-2	Brown	Hairs on upper portion	Straw	Medium	Red	Short and fully awn	Black	Medium
Padi Tanjung	Straw	Short hair	Red	Medium	Red apex	Absent	Awnless	Slender
Padi Nek Alui	Straw	Short hair	Straw	Medium	Straw	Absent	Awnless	Slender
Inpago-12 Agritan	Straw	Short hair	Gold	Long	White	Absent	Awnless	Slender
Inpago-13 Fortiz	Straw	Glabrous	Straw	Medium	Purple	Absent	Awnless	Slender

Table 3. Diversity of quantitative grain characteristics of local upland rice cultivars from exploration in Sarolangun and Merangin Regencies, Jambi Province.

Cultivars	Grain Length (mm)		Grain Width (mm)		Grain Thickness (mm)		Grain length:width	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Bakang	8.60	0.46	2.26	0.10	1.67	0.08	3.80	0.12
Godang	7.91	0.34	3.30	0.23	2.19	0.15	2.41	0.24
Endek	8.09	0.64	3.14	0.27	1.97	0.09	2.60	0.41
Harum	8.98	0.42	2.46	0.15	1.83	0.11	3.67	0.29
Bungo Kelapo	9.46	0.45	2.76	0.08	2.08	0.07	3.43	0.17
Air Mas	9.05	0.57	2.71	0.13	1.99	0.09	3.34	0.18
Ekor Kuda	9.16	0.71	2.18	0.21	1.86	0.09	4.24	0.50
Kubu	6.89	0.45	3.79	0.09	2.42	0.06	1.82	0.13
Bungo Duku	7.08	1.98	2.70	0.21	2.03	0.17	2.63	0.77
Kasah	9.13	0.74	2.73	0.24	2.05	0.12	3.36	0.20
Silang	8.74	0.47	2.49	0.12	2.04	0.05	3.52	0.19
Ruyung	8.13	0.34	3.76	0.15	2.38	0.17	2.16	0.07
Seni Kuning	8.63	0.29	2.89	0.08	2.05	0.06	2.99	0.10
Perak Putih	8.10	0.34	3.09	0.10	1.99	0.07	2.62	0.10
Seni Ruyung	8.81	0.54	2.07	0.11	1.69	0.07	4.26	0.19
Rejang	7.95	0.43	2.86	0.11	1.90	0.10	2.78	0.20
Cenano	7.50	0.45	2.59	0.12	1.92	0.07	2.89	0.19
Bungo Kelapo Kuning	7.74	0.25	2.89	0.07	2.01	0.13	2.68	0.11
Perak	7.93	0.19	3.58	0.16	2.15	0.08	2.22	0.10
Payo	7.77	0.28	3.24	0.13	2.05	0.07	2.40	0.17
Jambi-1	7.38	0.37	2.84	0.26	1.85	0.10	2.62	0.28
Kecik Kancil	8.79	0.35	2.63	0.13	1.95	0.06	3.35	0.22
Rambai Kuaw	8.75	0.41	2.42	0.19	1.72	0.07	3.65	0.40
Putih	7.79	0.56	2.71	0.18	1.91	0.33	2.88	0.24
Utal	6.92	0.38	2.59	0.12	1.84	0.09	2.68	0.23
Kecik Seni	8.65	0.49	2.18	0.07	1.71	0.12	3.97	0.21
Temiang Merindu	8.92	0.21	2.51	0.15	1.76	0.14	3.57	0.23
Bungo Belimbing	9.80	0.39	2.83	0.10	2.24	0.29	3.47	0.20
Alui	7.64	0.25	3.28	0.24	2.14	0.09	2.34	0.18
Gedang Putih	8.49	0.35	2.32	0.07	1.75	0.13	3.67	0.19
Halus	8.83	0.55	2.79	0.11	1.90	0.15	3.17	0.18

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Cultivars	Grain Length (mm)		Grain Width (mm)		Grain Thickness (mm)		Grain length:width	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Terong	6.60	0.39	3.42	0.16	1.97	0.09	1.93	0.16
Seni Kuku Balam	9.27	0.53	2.25	0.16	1.85	0.05	4.14	0.37
Seni Ekor Kuda	8.43	0.36	2.45	0.11	1.87	0.07	3.45	0.24
Seni Kabut	7.16	0.35	2.75	0.16	1.87	0.08	2.61	0.19
Empat Bulan	8.69	0.30	3.39	0.08	2.17	0.17	2.56	0.11
Mayang Rindu	8.78	0.54	2.69	0.18	1.82	0.18	3.28	0.24
Bungo Cempako	7.84	0.45	3.56	0.35	2.07	0.20	2.21	0.17
Kabut	8.27	0.46	2.65	0.27	1.81	0.07	3.15	0.30
Seni	8.44	0.56	2.47	0.26	1.84	0.06	3.45	0.43
Bungo Buluh	7.68	0.49	3.40	0.28	1.94	0.22	2.26	0.18
Buah Bernai	6.45	0.21	3.29	0.12	2.12	0.12	1.96	0.09
Bujang	8.13	0.49	3.35	0.23	2.16	0.15	2.44	0.23
Jambi-2	7.44	0.61	2.95	0.20	2.08	0.35	2.52	0.18
Padi Tanjung	8.11	0.60	2.61	0.21	1.88	0.04	3.14	0.45
Padi Nek Alui	8.69	0.55	2.40	0.13	1.81	0.07	3.63	0.35
Inpago-12 Agritan	9.77	0.33	2.69	0.18	2.35	0.41	3.64	0.29
Inpago-13 Fortiz	9.34	0.44	2.61	0.14	2.02	0.22	3.60	0.30
Min	6.45		2.07		1.67		1.82	
Maks	9.80		3.79		2.42		4.26	

Note : Stdev = Standard deviation.

DISCUSSION

The results of exploration revealed that Jambi upland rice cultivars showed diversity in their qualitative and quantitative traits. Qualitative traits such as the presence of hairs on the grain tip (awn) and characters related to colour, such as lemma and palea colour, sterile lemma colour, and apiculus colour, particularly anthocyanin coloration, are indicative of tolerance to abiotic stresses. Plant tissues with high anthocyanin content are generally tolerant to drought and salinity [3]. Anthocyanins protect plants from environmental stresses such as drought, high light intensity, and salinity [17, 20]. Anthocyanins act as antioxidants by modulating antioxidant enzymatic activity and drought-responsive gene expression [10], scavenging ROS (Reactive Oxygen Species) and protecting plants from oxidative damage [5]. The capability of plants to survive under water-limited conditions was due to osmotic adjustment between osmotic potential and anthocyanin content [33]. According to Nounjan and Theerakulpisut [23], osmotic adjustment was a key mechanism mitigating the negative impacts of salinity stress on purple-leaved rice.

The results showed great differences in the quantitative grain traits among cultivars. Grain length ranged from 6.45 to 9.8 mm; grain width from 2.07 to 3.79 mm; grain thickness from 1.67 to 2.42 mm; and grain length:width ratio ranged from 1.82 to 4.2. These characteristics contribute to the diversity in grain shape, which is classified as long, medium, and round. Jeyasri *et al.* [11] and Wang *et al.* [32] suggested that grain shape was influenced by abiotic stresses such as drought, high temperature, and salinity. Identification of genes associated with stress-induced changes in grain morphology is key to develop stress-tolerant crops. Cluster analysis using the Unweighted Pair Group Method with Arithmetic Means (UPGMA) method using the Numerical Taxonomy System (NTSYS) program showed the presence of five accession groups at a 50% similarity level (Fig. 1). This indicates broad differences in genetic background resulting from adaptation to environmental conditions during the evolutionary process. Cultivars within the same group showed a high level of genetic similarity, while those in different groups showed genetic differences.

The evaluated cultivars mostly clustered in Cluster I, with 22 cultivars in the same group as the tolerant reference cultivar (Inpago-12 Agritan). Twelve cultivars clustered in Cluster II with the moderately tolerant reference cultivar Inpago-13 Fortiz. Cluster III formed a separate group at a 30% similarity level, suggesting that these groups share a distantly related ancestor. The Kasah, Buah Bernai, and Jambi-2 cultivars formed a distinct cluster which was different from the other clusters, indicating a large genetic distance and potential for use as crossbreeding parents. Cultivars within the same cluster are thought to have experienced similar selection pressures during their evolution. These selection pressures can include environmental conditions and selection of specific traits during cultivation [2, 29].

Drought tolerance is the ability of a plant to produce maximum yield under limited water conditions [8, 13, 27]. Rainfed ecosystems contribute to only 25% of the total water supply, thereby making rice more vulnerable to increased frequency of drought stress. Drought stress results in physiological, biochemical, and morphological changes in upland rice [14].

Drought tolerance in rice is genetically a complex trait controlled polygenically and involves complex morphophysiological mechanisms [18]. In rice, tolerance is primarily demonstrated by the ability of root system to meet evapotranspiration needs and its capacity for osmotic adjustment [21]. In addition to this, Nguyen *et al.* [22] stated that osmotic adjustment allows plants to maintain turgor pressure and protect meristems. Plant responses to tissue water potential determine the degree of drought tolerance [19], and traits related to these phenomena are considered secondary traits. Secondary traits such relative water content, leaf rolling, and

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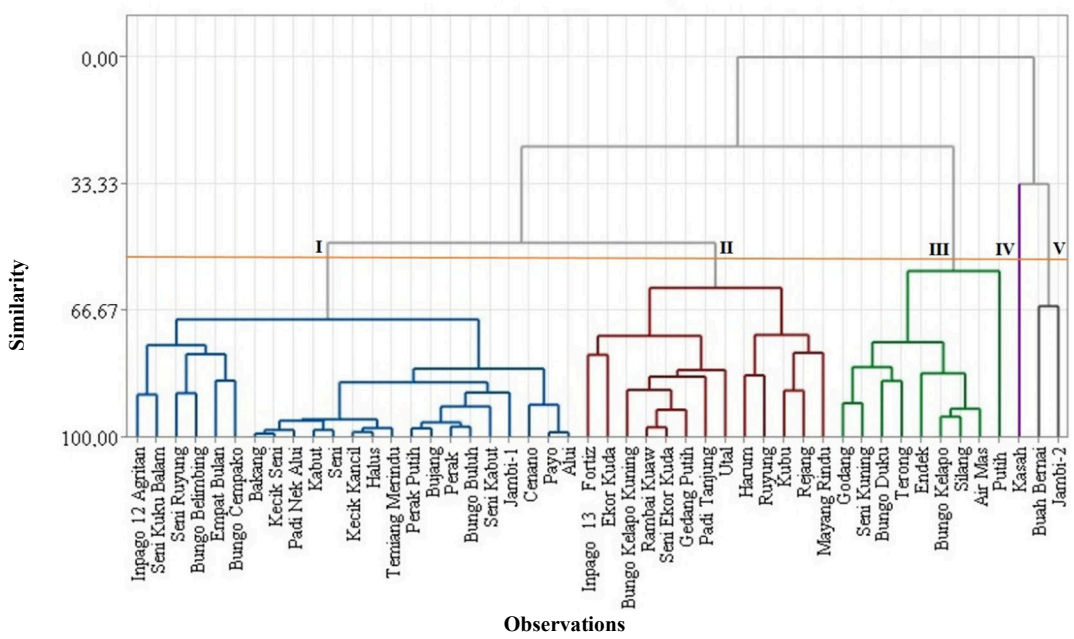


Figure 1. Dendrogram analysis showing grain morphological diversity of 2 reference cultivars and 46 local upland rice cultivars from Jambi Province, Indonesia.

stomatal conductivity have been used for selection [1, 12, 26].

Drought tolerance in rice is genetically a complex trait controlled polygenically and involves complex morphophysiological mechanisms [18]. In rice, tolerance is primarily demonstrated by the ability of root system to meet evapotranspiration needs and its capacity for osmotic adjustment [21]. In addition to this, Nguyen *et al.* [22] stated that osmotic adjustment allows plants to maintain turgor pressure and protect meristems. Plant responses to tissue water potential determine the degree of drought tolerance [19], and traits related to these phenomena are considered secondary traits. Secondary traits such relative water content, leaf rolling, and stomatal conductivity have been used for selection [1, 12, 26]. Further, a study by Lanna *et al.* [15] concluded that morphophysiological characteristics associated with drought tolerance in upland rice included high leaf water storage capacity, low leaf water potential, high vegetative structure reduction, high water use efficiency, high photosynthetic capacity, and increased soil water absorption capacity through osmotic adjustment or root system development.

Rice plant changes and responses to drought vary depending on the growth phase of the plant at the time of the drought (seedling, vegetative, or reproductive), the intensity of drought stress (mild or severe), and other environmental conditions. Genetic and physiological differences in drought response are also related to genotypic differences . A thorough understanding of the forms of change and the mechanisms of specific rice varieties' responses to drought is crucial for selecting location-specific drought-tolerant varieties.

The adaptation to various regions with different agro-ecological conditions was thought to be the results of environmental pressure during natural selection process. Topographically, Jambi Province is located at a highly variable altitude, ranging from 0 to 1,000 meters above sea level, with elevations increasing westward, in the Bukit Barisan mountain range. The Sarolangun and Merangin Regencies, where the exploration took place, is located at three altitude groups: lowlands (0-100 m above sea level), medium lands (100-500 m above sea level), and highlands (>500 m above sea level).

This study revealed that exploration conducted in six sub-districts in Sarolangun Regency and one sub-district in Merangin Regency collected 48 local upland rice cultivars which showed diversity in grain morphology and several morpho-agronomic traits during initial field testing. The local upland rice cultivars showed diversity in qualitative grain traits related to stress tolerance, namely lemma and palea colour, sterile lemma colour, apiculus colour, and the presence of hairs on grain. This diversity indicates the potential use of local upland cultivars in plant breeding programs to develop drought stress-tolerant cultivars. Cluster analysis based on grain morphology showed that local upland rice cultivars evaluated at a 50% similarity level formed five clusters, indicating genetic distance between cultivars.

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