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The Diversity of Agronomic Characteristics of Several Local Aceh Rice Germplasm

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Abstract

To accelerate the target of national food self-sufficiency, especially rice, the development of upland rice that has high yields and is adaptive to extreme environments is needed. Fulfillment of high-yielding characteristics begins with characterization and selection to get the most adaptive varieties. This study aims to identify the morpho-physiological characteristics of Aceh rice germplasm. The study was conducted in Gampong Paloh Lada and at the Agroecotechnology Laboratory, Faculty of Agriculture, Universitas Malikussaleh, Aceh Utara Regency, and at the Biology Laboratory in Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, from April to August 2022. This research used a Randomized Block Design non Factorial, comprising 7 local inbreds viz., Unsyiah Cakep (G1), Unsyiah Seumeulu (G2), Cot Bada (G3), Sigunca (G4), Sigupai (G5), Cot Bada (G6) and Rajasa (G7). The parameters measured were growth and yield variables consisting of plant height, number of tillers, flowering age, leaf proline content, root length, shoot-root ratio, number of grains, and weight of 1000 grains. The results indicated that the local germplasm Sigunca and Sigupai have good adaptability by adjusting plant height and forming more tillers than other germplasm. In terms of generative growth, Unsyiah Mantap and Cot Bada are entering generative growth more quickly, as marked by the appearance of flowers. The proline content as an indicator of resistance to water limitations was achieved at the highest level in Unsyiah Cakap at 5 g/mol, followed by Unsyiah Mantap at 3 g/mol.

Keywords: Local germplasm; Aceh Rice; Proline; Tolerant inbred.

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1. Introduction

Rice (*Oryza sativa* L.) is one of the leading crops in the world and in Indonesia this staple food plays a pivotal role as a strategic commodity. Almost 50% of the world's population uses rice as a staple food [1]. Countries in East Asia, South Asia and Southeast Asia dominate the production and consumption of rice worldwide. Historically, more than 90% of world rice production was contributed by these countries [2]. Its production needs to be increased by 0.6%-0.9% per year until 2050 to feed a further 2 billion people [3]. The increase in population in Indonesia contributed to the higher consumption of rice. Statistics Indonesia (2021) informed that there is a decrease in rice production in Aceh, from 1.7 tons/ha in area 317,869,41 ha to 1.6 tons/ha in area 279,058,41 ha in 2020.

Water availability is considered an important factor affecting rice production [4]. Rice is extremely sensitive to drought [5, 6]. Abiotic stress affects plants' development and growth rate at physiological and biochemical levels, which is the basis for expanding the efficiency of crop products [7, 8]. Drought is one the most significant abiotic stress which disables the plants to perform better, resulting in a decrease in harvest and national production targets every year worldwide [9-11]. The period and development of stress, different phases of plant growth and development, and biotic and abiotic elements can influence the response to abiotic stress [12].

Climate changes worsen the drought phenomenon [13-17]. Over the past 50 years, the Earth's temperature has increased by 0.74°C, causing floods, drought, hurricanes/typhoons and high tides. Regarding this, Mahalle, *et al.* [18] reported that rice production lowered to 65% compared to rice cultivated in irrigated areas.

There are 34 million ha of rainfed rice fields and 8 million ha of upland rice fields troubled by drought stress [19]. This abiotic stress can occur during rice development [20], for instance, in seedlings, where it causes improper growth and decreased yield [21]. Some investigations found that drought stress negatively affected the germination phase, seed vigor, photosynthesis activity, leaf membrane stability and osmotic content [22, 23].

Aceh Province possesses numerous local inbred genotypes, and these genotypes have not been screened for their tolerance against drought stress. Through exploration of rice production centers in Aceh, we collected 50 local inbred genotypes. However, only a few of them have been examined for their resistance to drought stress [24]. Aceh

Province has been known to have plenty of local rice germplasms. Therefore, it is important to maintain its sustainability for the community's survival. Local germplasm exhibits potential genes, determining superior genes in rice [25]. The existence of local varieties is strongly required as genetic resources in rice plant breeding. The application of these genes could increase rice plant productivity in several countries [26].

Identification is an initial activity, considered the spearhead of agricultural development. This activity plays an important role in preventing the possibility of local germplasm extinction or genetic resource occupation by another country [27]. [28] explained that this activity is essential for plant description. The characteristics of drought-stress tolerance in local rice in Aceh is scarce. Therefore, a study for genetic variability and morphology identification is important to be conducted in Aceh rice germplasm to obtain several data about these local inbreds, to protect the gene richness to enrich the gene pool by exploring and finding new gene variability from these local inbreds to produce new superior varieties [29]. This study aims to identify the morphophysiological characters of Aceh rice germplasm.

2. Materials and Methods

Field research was carried out in Gampong Paloh Lada, at an altitude of 35 m above sea level and at the Laboratory of Agroecotechnology, Faculty of Agriculture, Malikussaleh University, while the proline analysis was carried out at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, North Sumatra University from April to August 2022. The 7 local germplasms were applied in non-irrigated fields (watered only in 2-day intervals) after being screened for their tolerance to drought in a laboratory.

The materials used in this research were 7 local germplasms from Aceh such as local inbred (Unsyiah Cakep (UC 77), Unsyiah Seumeulu (US20), Cot Bada (CBD08), Sigunca (SG02), Sigupai (UA12), Cot Bada (CBD04) and Rajasa, fertilizers NPK and cow manure, polybag (50 x 40 cm), label paper, several chemical compounds for amino acid analysis (toluene, DL proline, ninhydirin, sulphosalicylic acid 3%, H_3PO_4). The equipment used were a hoe, machete, measuring tape, sack, buckets (55 cm × 22 cm), oven, hand sprayer, digital camera, analytical balance, rulers, water hoses, chlorophyll meter, leaf area meter, grain moisture meter, test tubes, scissors, mortar, aluminium foil and stationery.

This research employed Randomized Block Design (RBD) non Factorial comprising 7 local germplasms of Aceh rice: Unsyiah Cakep, UC 77 (G1), Unsyiah Seumeulu, US20 (G2), Cot Bada, CBD08 (G3), Sigunca, SG02 (G4), Sigupai, UA12 (G5), Cot Bada, CBD04 (G6) and Rajasa (G7). Each of local germplasms replicated for 3 times.

2.1. Data Analysis

All observational data were further analyzed using analysis of variance at the level of test = 0.05 and further analysis using Duncan's Multiple Range Test (DMRT). Data processing using the Windows version of the SAS statistical program (Version 9).

2.2. Research Implementation

The first step before the research is to determine the condition of the field capacity using the gravimetric method. This method is done by pouring water on the media until it is saturated, and left until the water stops dripping from the polybag. The planting medium used was first air-dried and pulverized by grinding and sifting with a size of 3 mm. The soil that has been smooth is mixed with cow manure at a dose of 10 tons per ha, Phonska + Urea compound fertilizer (300 kg/ha + Urea 200 kg/ha), after that the media is put into polybags measuring 50 cm x 40 cm.

2.3. Plant Preparation Material

For uniform germination, the seeds were oven-baked for 72 hours at 43 ^{0}C. After the seeds were roasted, 35 g of each variety were weighed, then the rice seeds were soaked in a mixture of Dithane M 45 as much as 2 g/l and Curater 2G as much as 0.1 g. Dithane M 45 is needed to prevent late blight. While Curator 2G is needed to prevent pests in the soil. The seed treatment mixture is added with sufficient water and then the rice seeds are added and soaked for 24 hours.

2.4. Maintenance

Plant maintenance includes eradicating pests and diseases using the insecticide Baycarb with a concentration of 0.5 – 1 l/ha. The frequency of spraying is carried out according to the conditions of pest and disease attacks. Weeds that grow in polybags are removed intensively.

2.5. Sprinkling

Watering is given every morning with as much sprinkling as 4 mm /day until harvest time.

2.6. Harvest

Harvesting is done when the rice grains have turned yellow, the grain is full and pithy, the flag leaves are yellow, some of the stems are dead, browned dry and the leaf stalks look bent.

2.7. Plant Height

Plant height was measured at the age of 10 days after planting (DAP), 30 DAP and 50 DAP. Measurements were made from the base of the stem to the tip of the highest leaf.

2.8. Number of Tillers

The number of tillers/clumps were counted when the plants were 10 DAP, 30 DAP and 50 DAP

2.9. Flowering Age

Flowering age is determined when panicles from several tillers have appeared, counting from the nth day after planting.

2.10. Leaf Proline Content

Proline levels were analyzed based on the method of Bates et al. (1973). The plant material used was the tip of the top leaf of the crown which had fully expanded as much as 0.5 g. The leaf pieces that had been cold-dried were weighed as much as 0.5 g, then crushed and homogenized with 10 ml of 3 percent sulfosalicylic acid. Then it was centrifuged at 9000 x g for 15 minutes. A total of 2 ml of the supernatant was reacted with 2 ml of ninhydrin acid and 2 ml of glacial acetic acid in a test tube and heated in a water bath at a temperature of 100 °C for 60 minutes. The solution was then cooled on ice for 5 minutes, the solution was extracted with 4 ml of toluene until chromoform was formed. To determine the proline content, the absorption of the colored solution was measured using a spectrophotometer at a wavelength of 520 nm. Meanwhile, as a standard, 0.1-3.0 mM of proline (sigma) was used which was dissolved in 3 percent sulfosalicylic acid. The proline content was expressed as mol g of dry base leaf. Measurements were made when the plants were 52 days after planting.

2.11. Root Length

Measurement of root length was carried out by measuring the longest root after being cleaned of adhering soil

2.12. Shoot – Root Ratio

Shoot-root ratio is a ratio between the dry weight (g) of the upper part of the plant (leaves, stems, flowers and fruit) with the lower part of the plant, namely the dry weight of the root (g).

2.13. Number of Grains Per Clump

The number of grains per clump is the number of grains in one clump which is calculated at the time of harvest

2.14. Weight of 1000 Grains of Pithy Grain

The weight of 1,000 grains of pithy grain is the weight of 1,000 grains of pithy grain that has been cleaned and dried until the water content reaches approximately 14 percent per clump.

3. Results and Discussion

3.1. Plant Height and Tiller Number

The results of ANOVA indicated that different local germplasms showed significant plant height and tiller number at 10, 30 and 50 days after planting (DAP) (Tabel 1).

Table-1. Plant height and Tiller number produced by different local germplasms at 10, 30 and 50 DAP

Germplasms	Plant Height (cm)			Tiller number		
	10 DAP	30 DAP	50 DAP	10 DAP	30 DAP	50 DAP
G1 = UC 77 (Unsyiah Cakep)	31.7^{c}	48.4^{c}	110.1^{c}	2.0^{a}	9.9^{b}	17.1^{ed}
G2 = US20 (Unsyiah Seumeulu)	$32.\ 3^{c}$	56.6^{b}	118.6^{b}	2.0^{a}	14.8^{a}	20.2^{bd}
G3 = UM9 (Unsyiah Mantap)	44.2^{a}	62.1^{a}	124.2^{a}	2.0^{a}	6.0^{b}	14.8^{e}
G4 =SG02 (Sigunca)	32.7^{c}	44.7^{c}	126.4^{a}	2.0^{a}	19.3^{a}	24.3^{ab}
G5 = US12 (Sigupai)	32.4^{c}	47.8^{c}	106.9^{c}	2.0^{a}	18.4^{a}	26.2^{a}
G6 = CBD04 (Cot Bada)	32^{c}	46.1^{c}	106.9^{c}	2.0^{a}	15.1^{a}	19.8^{cd}
G7 = Rajasa	41.1^{b}	58.0^{b}	103.1^{d}	2.0^{a}	16.7^{a}	23.7^{ac}

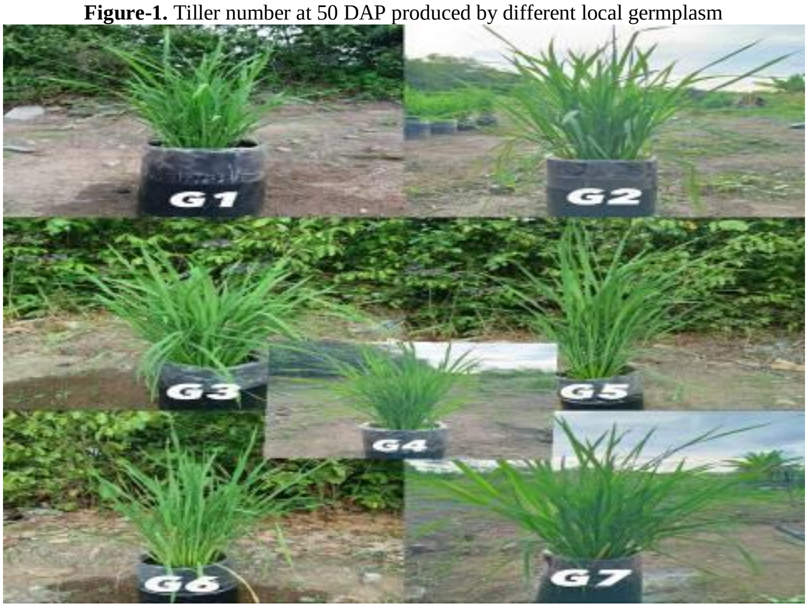
Note: the numbers followed by the same letter notation in the same column are not significantly different on the 5% Duncan's Multiple Range Test (DMRT). DAP= Days after planting.

Table 1 explained that Sigunca exhibited the highest plant height and Unsyiah Cakep possessed the lowest at 10 DAP, while at 30 and 50 DAP Rajasa revealed the lowest height. Local germplasms of Aceh rice germplasms showed different plant heights, indicating that this rice plant has been well adapted in several areas. Local rice is the potential to be a resource for the development of superior varieties. Saridas, *et al.* [11] stated that each variety has its own distinguishing characteristic, which can be enhanced through crossbreeding. Zhang, *et al.* [30] also added that the plant height is influenced by its genetics and surrounding environment.

IRRI [31] confirmed that a plant height of 110 cm at 60 DAP is considered low. The examined local inbred possessed height of more than 110 cm at > 60 DAP. The difference in heights demonstrated by these 7 screened inbreds is attributed to a genetic factor. As a matter of fact, each variety exhibits different characteristics, both qualitatively and quantitatively [32]. In addition to genetic influences, each of these varieties is also influenced by environmental factors that can cause gene mutations. Gene mutations will occur when a variety is grown in areas with cold temperatures and then the results are reproduced in areas with hot temperatures, and vice versa [33].

The table above shows that germplasm Sigunca (G4) exhibited the highest number of tillers at 30DAP, while germplasm Unsyiah Mantap (G3) found to produce the lowest. In Table 1 and Figure 1 we also gave the result of tiller number at 50 DAP, Sigupai (G5) exhibited the highest number of tillers with 26.2 sheet, and followed by Sigunca (G4), Rajasa (G7), Unsyiah Seumeulu (G2), Cot Bada (G7), Unsyiah Cakep (G1), and Unsyiah Mantap (G3), consecutively. Tiller growth at the beginning of the vegetative period is an important process that determines the number of productive tillers that not only contribute to rice grain yields but also the ability to recover from unsuitable growing conditions [34, 35].

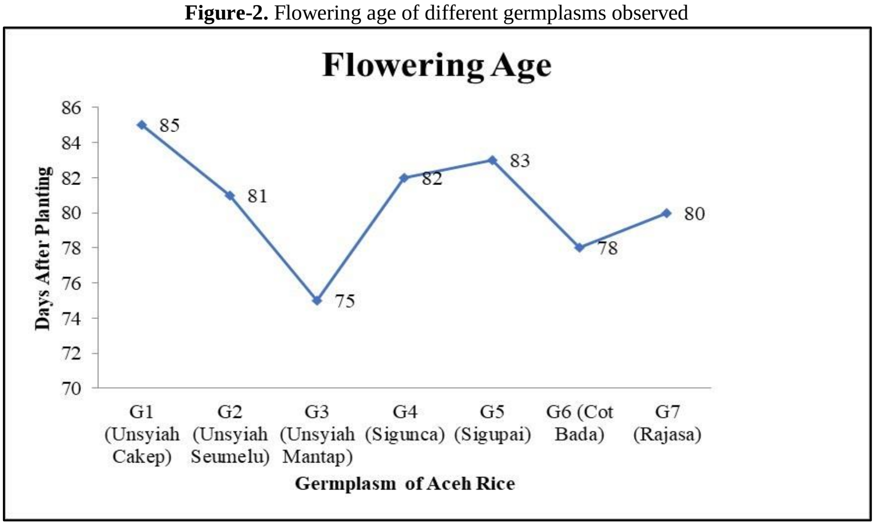
Figure-1. Tiller number at 50 DAP produced by different local germplasm



3.2. Flowering Age

This variable is significantly influenced by the development of each germplasms. According to the observations (Figure 2), the germplasms Unsyiah Mantap and Cot Bada flowered faster than the other germplasms, 75 and 78 DAP, respectively. Vice versa, Unsyiah Cakep (G1) began to experience the flowering phase at the age of 85 days after planting, 10 days later than Unsyiah Mantap. This occurrence was documented based on their ages, which ranged from 105 to 130 DAP. The plant life cycle depends on the plant genotype and environmental conditions [36]. Adaptation to drought is possible due to shorter life cycles or growing seasonally and allowing plants to reproduce before the environment becomes dry [37]. In the short life cycle of rice plants, adaptation to extreme environments such as drought can be in the form of earlier flowering, which is considered a form of adaptation to drought by avoiding stress.

Figure-2. Flowering age of different germplasms observed



3.3. Proline Compound Content (g/mol)

The sensitivity of each cultivar to drought stress can differ depending on the resistance character of each cultivar [38]. One important parameter that shows tolerance to drought is proline content. Drought increases cell proline levels in two ways: by increasing proline synthesis and by reducing the activity of enzymes involved in its degradation. Low turgor pressure is the first reason for proline accumulation under drought stress. There is a close relationship between proline accumulation and plant resistance to drought stress [39]. Figure 3 depicts the proline contents at 60 DAP in our study.

Figure-3. Proline content in different germplasms observed

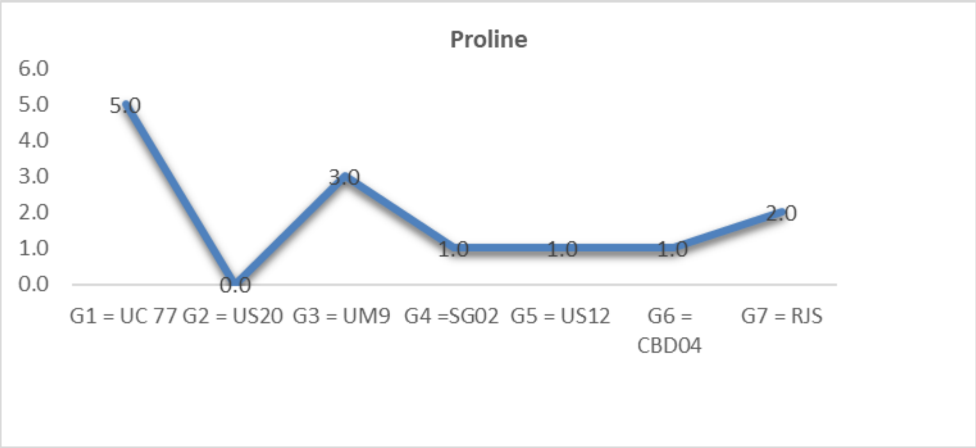


Figure 3 explained that the highest proline content was found in germplasm Unsyiah Cakep, followed by Unsyiah Mantap. The lowest was exhibited by Unsyiah Semeulu. Proline plays an essential role in producing drought tolerance, where this compound is taken from leaf tissue. The use of 30-40% PEG 6000 successfully increased the drought tolerance [40]. The ability of proline to keep nitrogen, as an osmoregulator, and as a protector of several important enzymes allows the plant to have higher tolerance as a result of high proline content production. Plants with higher proline content exhibited better performance against drought. Besides, proline also prevents turgor pressure and low osmotic activity [41].

3.4. Root Length and Root Ratio

The root length at 10, 30 and 50 DAP and root ratio at 20, 40 and 60 DAP were presented in Table 2.

Table-2. Root length and root ratio produced by different local germplasms at 20, 40 and 60 DAP

Germplasms	Root length			Root Ratio		
	10 DAP	30 DAP	50 DAP	20 DAP	40 DAP	60 DAP
G1 = UC 77 (Unsyiah Cakep)	9.1 c	23.7 a	27.1 c	1.8 ab	3.1 a	33.1a
G2 = US20 (Unsyiah Seumeulu)	11.1 a-c	25.3 a	26.3 c	1.04 b	0.7 b	28.03 b
G3 = UM9 (Unsyiah Mantap)	10.7 a-c	12.5 b	38.5 a	0.8 b	3.2 a	22.8 c
G4 =SG02 (Sigunca)	14.3 ab	20.3 ab	26.5 c	1.5 ab	0.8 b	28.7 b
G5 = US12 (Sigupai)	13.0 a-c	18.7 ab	27.6 c	4.5 a	0.6 b	26.1 b
G6 = CBD04 (Cot Bada)	9.7 bc	18.7 ab	33.8 b	1.9 ab	1.1 b	28.1 b
G7 = Rajasa	15.0 a	22.7 a	29.4 cb	2. 4 ab	1.7 b	29.2 b

Note: the numbers followed by the same letter notation in the same column are not significantly different on the 5% Duncan's Multiple Range Test (DMRT). DAP= Days after planting

Germplasms Unsyiah Mantap was found to have the longest root compared to other varieties and the lowest was shown by Cot Bada. Roots are the main tissue for absorbing water from the soil. Therefore, root growth rate, density, proliferation, and size are key factors influencing plant response to drought stress [42]. Root length determines plant tolerance to drought, where the roots develop better to absorb more water and nutrient to survive. Zu, *et al.* [43], Yang, *et al.* [44] and Ullah, *et al.* [45] reported that root length and diameter are important indicators determining the tolerance level of rice to drought in upland fields. The tolerant plants possess more ability to develop longer roots compared to the moderate and vulnerable plants. Hazman and Brown [46] confirmed that root response to drought increased the ability of plants to grow better. Rice roots exposed to drought stimulate the signal as a response to drought stress by regulating the stomata conductance, proline, repiration activity and crown growth [47].

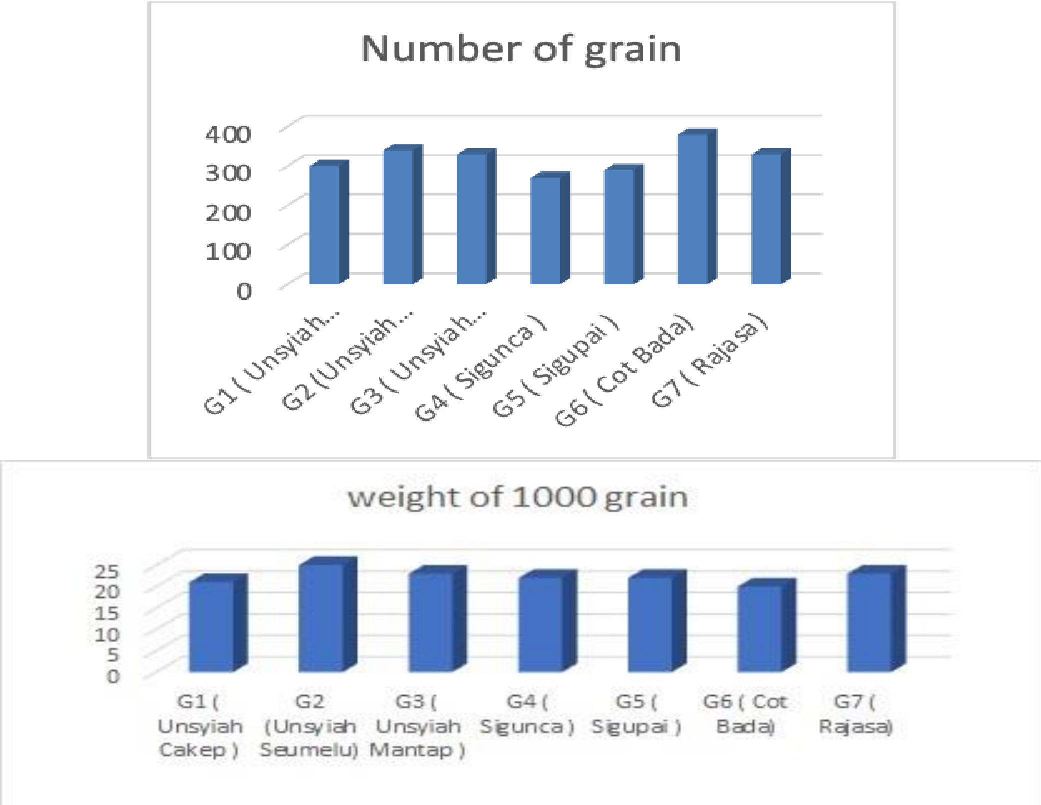
Germplasm Unsyiah Seumeulu demonstrated the highest root ratio compared to other germplasms and the lowest was exhibited by Unsyiah Mantap. The resistant germplasms produced lower root weight compared to vulnerable ones. Nazirah, *et al.* [48] stated that plant response to drought can be analysed by identifying the characteristics affecting their tolerance, such as shoot ratio or proline content in leaves. The different treatments between upland rice paddy rice contributed by water use and also root growth and drought tolerance [49]. This phenomenon explains that the vulnerable germplasms are able to perform better in optimal and conducive conditions, whereas if the plants are exposed to drought, the decrease in plant weight is significant.

Generally, tolerant varieties increase root growth to combat drought stress. The mechanisms applied by plants to fight the drought by: (i) decreasing the leaf area and shortening the development cycle, (ii) absorbing more water obtained from deeper soil layers, (iii) protecting root meristem from drought by enhancing the accumulation of glycin, betain, sugar alcohol and proline for adjusment and (iv) optimizing the role of stomata to prevent water loss through leaves [50]. Osmotic adjusment allowed plant to keep growing and the stomata to perform better.

3.5. Grain Yield and 1000-Seed Weight

Different germplasms indicated significant number of grain yield and 1000-seed weight (Figure 4).

Figure-4. Number of grains and 1000-seed weight exposed by different germplasms exposed



This figure described that germplasm Cot Bada presented the highest number of grains compared to other germplasms, while Sigunca exhibited the lowest. Unsyiah Seumeulu was recorded to have the highest 1000-seed weight, followed by Rajasa, and Cot Bada was the lowest. It assumed that the size of seeds contributed to the 1000-seed weight. The size of the seed is also related to skin size, according to Ahmad et al. (2022), who discovered that 1000-seed weight determines the stable character of an accession. However, the seed size was measured after emerged from the skin. Therefore, 1000-seed weight has described the quality of seeds [27].

4. Conclusion

The findings of our research provide information on the potential of several Acehnese local rice germplasms that can be developed into local rice that can be widely cultivated. This can be seen from the morphophysiological characters tested. Sigunca and Sigupai have good adaptability by adjusting plant height and forming more tillers than other germplasm. However, in terms of generative growth, Unsyiah Mantap and Cot Bada are entering generative growth more quickly as marked by the appearance of flowers. Unsyiah Cakap had the highest proline content as an indicator of resistance to water limitations, at 5 g/mol, followed by Unsyiah Mantap at 3 g/mol.

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References

[1] Zafar, S. A., Hameed, A., Nawaz, M. A., Ma, W., Noor, M. A., and Hussain, M., 2018. "Mechanisms and Molecular Approaches for Heat Tolerance in rice (*Oryza Sativa* L.) under Climate Change Scenario." *J. Integr. Agric.*, vol. 17, pp. 726-738. Available: 10.1016/S2095-3119(17)61718-0

[2] Barker, R., Dawe, D., Tuong, T., Bhuiyan, S., and Guerra, L., 1999. "The outlook for water resources in the year 2020: Challenges for research on water management in rice production. *Southeast Asia*." vol. 1, pp. 1-5.

[3] Desa, U., 2015. "United Nations Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2015 Revision, Key Findings and advance Tables. New York: Online Edition UN DESA."

[4] Bouman, e. a., 2017. "Rice and Water." *Adv. in Agron.*, pp. 187-237.

[5] Fischer, K. S. and Fukai, S., 2003. "How rice responds to drought. Breeding rice for drought-prone environments." vol. 1, p. 32.

[6] Wening, R. H. and Susanto, U., 2014. "Skrining plasma nutfah padi terhadap cekaman kekeringan." *Widyariset,* vol. 17, pp. 193-203.

[7] Akram, R., Fahad, S., Masood, N., Rasool, A., Ijaz, M., Ihsan, M. Z., and Nasim, W., 2019. *Plant growth and morphological changes in rice under abiotic stress. In Advances in rice research for abiotic stress tolerance*. Woodhead publishing, pp. 69-85.

[8] Kazan, K., 2015. "Diverse roles of jasmonates and ethylene in abiotic stress tolerance." *Trends in plant science,* vol. 20, pp. 219-229.

[9] Mas-ud, M., Matin, M. N., Fatamatuzzohora, M., Ahamed, M., Chowdhury, M., Paul, S. K., and Hossain, M., 2022. "Screening for drought tolerance and diversity analysis of Bangladeshi rice germplasms using morphophysiology and molecular markers." *Biologia,* vol. 77, pp. 21-37.

[10] Mishra, S. S., Behera, P. K., and Panda, D., 2019. "Genotypic variability for drought tolerance-related morpho-physiological traits among indigenous rice landraces of Jeypore tract of Odisha, India." *Journal of Crop Improvement,* vol. 33, pp. 254-278.

[11] Saridas, M. A., Simsek, O., Donmez, D., Kacar, Y. A., and Kargi, S. P., 2021. "Genetic diversity and fruit characteristics of new superior hybrid strawberry (Fragaria× ananassa Duchesne ex Rozier) genotypes." *Genetic Resources and Crop Evolution,* vol. 68, pp. 741-758.

[12] Feller, U. and Vaseva, I. I., 2014. "Extreme climatic events: impacts of drought and high temperature on physiological processes in agronomically important plants." *Frontiers in Environmental Science,* vol. 2, p. 39.

[13] Cheeseman, J., 2016. *Food Security in the Face of Salinity, Drought, Climate Change, and Population Growth.In Halophytes for Food Security in Dry Lands, edited by M. A. Khan, M. Ozturk, B. Gul, and M. Z. Ahmed*. San Diego: Academic Press. pp. 111–123.

[14] Dada, O. A., Kutu, F. R., and Mavengahama, S., 2021. "Improving crop physio-biochemical efficiency and abiotic resilient crops for alleviating food insecurity in Africa." *Food Security and Safety,* pp. 375-392.

[15] Kang, M. S. and Banga, S. S., 2013. "Global agriculture and climate change." *Journal of Crop Improvement,* vol. 27, pp. 667–692.

[16] Khush, G. S., 2015. "Punjab's Water Woes and India's Food Security." *Journal of Crop Improvement,* vol. 29, pp. 1-5. Available: 10.1080/15427528.2015.997655

[17] Lesk, C., Rowhani, P., and Ramankutty, N., 2016. "Influence of extreme weather disasters on global crop production." *Nature* vol. 529, pp. 84–87.

[18] Mahalle, M. D., Dey, P. C., Chetia, S. K., Baruah, A. R., Ahmed, T., Sarma, R. N., and Modi, M. K., 2021. "Association mapping for yield traits under drought stress in Autumn rice germplasm collection of Assam." *Journal of Plant Biochemistry and Biotechnology,* vol. 30, pp. 26-36.

[19] Singh, R., Singh, Y., Xalaxo, S., Verulkar, S., Yadav, N., and Singh, S. S., 2016. "From QTL to Variety-Harnessing the Benefits of QTLs for Drought, Flood and Salt Tolerance in Mega Rice Varieties of India through a Multi-Institutional Network." *Plant Science,* vol. 242, pp. 278–287. Available: 10.1016/j.plantsci.2015.08.008

[20] Abdelaty, M. S., El-Abd, A. B., Ibrahim, M. H., Youssif, A., Batool, M., Sami, R., and Hassan, H. M., 2022. "Identification of drought tolerant rice genotypes based on morpho-Physiological and yield traits under normal and drought stress conditions." *Journal of Biobased Materials and Bioenergy,* vol. 16, pp. 390-401.

[21] Bishwajit, G., Sarker, S., Kpoghomou, M. A., Gao, H., Jun, L., Yin, D., and Ghosh, S., 2013. "Self-sufficiency in rice and food security: a South Asian perspective." *Agriculture and Food Security,* vol. 2, pp. 1-6.

[22] Bhattacharjee, S. and Dey, N., 2017. "Redox metabolic and molecular parameters for screening drought tolerant indigenous aromatic rice cultivars." *Physiology and Molecular Biology of Plants,* Available: 10.1007/s12298-017-0484-1

[23] Pandey, V. and Shukla, A., 2015. "Acclimation and tolerance strategies of rice under drought stress." *Rice Science,* vol. 22, pp. 147-161.

[24] Bin, R. A. R. and Zhang, J., 2016. "Flood and drought tolerance in rice: opposite but may coexist." *Food and Energy Security,* vol. 5, pp. 76-88.

[25] Rabello, A. R., Guimarães, C. M., Rangel, P. H., da Silva, F. R., Seixas, D., de Souza, E., and Mehta, Â., 2008. "Identification of drought-responsive genes in roots of upland rice (*Oryza sativa* L)." *BMC genomics,* vol. 9, pp. 1-13.

[26] Brar, D. S. and Khush, G. S., 2018. "Wild relatives of rice: a valuable genetic resource for genomics and breeding research." *In The wild Oryza genomes,* pp. 1-25.

[27] Setyowati, M., Irawan, J., and Marlina, L., 2018. "Karakter Agronomi Beberapa Padi Lokal Aceh." *Jurnal Agrotek Lestari*, vol. 4, pp. 36-50.

[28] Bhatia, D., Joshi, S., Das, A., Vikal, Y., Sahi, G. K., Neelam, K., and Singh, K., 2017. "Introgression of yield component traits in rice (*Oryza sativa ssp. indica*) through interspecific hybridization." *Crop Science*, vol. 57, pp. 1557-1573.

[29] Neeraja, C. N., Hariprasad, A. S., Malathi, S., and Siddiq, E. A., 2005. "Characterization of tall landraces of rice (*Oryza sativa* L.) using gene-derived simple sequence repeats." *Current Science*, vol. 88, pp. 149-152.

[30] Zhang, H., Liu, K., Wang, Z., Liu, L., and Yang, J., 2015. "Abscisic acid, ethylene and antioxidative systems in rice grains in relation with grain filling subjected to postanthesis soil-drying." *Plant Growth Regulation*, vol. 76, pp. 135-146.

[31] IRRI, 1996. "Standard Evaluation System for Rice. Los Banos-Philippines: International Rice Research Institute."

[32] Mau, Y. S., Markus, J. E., Shirly, S., Oematan, S., Ndiwa, A. S. S., Handoko, D. D., and Makbul, K., 2017. "Genetic diversity of red and black upland rice accessions from East Nusa Tenggara, Indonesia as revealed by agro-morphological characters." *Biodiversitas Journal of Biological Diversity*, vol. 18.

[33] Efendi, E., Halimursyadah, H., and Simajuntak, H. R., 2012. "Respon pertumbuhan dan produksi plasma nutfah padi lokal Aceh terhadap sistem budidaya aerob." *Jurnal Agrista*, vol. 16, pp. 114-121.

[34] Larkunthod, P., Nounjan, N., Siangliw, J. L., Toojinda, T., Sanitchon, J., Jongdee, B., and Theerakulpisut, P., 2018. "Physiological responses under drought stress of improved drought-tolerant rice lines and their parents." *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, vol. 46, pp. 679-687.

[35] Singh, B., Reddy, K. R., Redoña, E. D., and Walker, T., 2017. "Screening of rice cultivars for morpho-physiological responses to early-season soil moisture stress." *Rice Science*, vol. 24, pp. 322-335.

[36] Akhtar, I. and Nazir, N., 2013. "Effect of water logging and drought stress in plants." *Int. J. Water Res. Environ Sci.*

[37] Berger, J., Palta, J., and Vadez, V., 2016. "An integrated framework for crop adaptation to dry environments: Responses to transient and terminal drought." *Plant Science*, vol. 253, pp. 58-67.

[38] Cabello, J. V., Lodeyro, A. F., and Zurbriggen, M. D., 2013. "Novel perspectives for the engineering of abiotic stress tolerance in plants." *Curr. Opin Biotechnol*, vol. 26, pp. 62-70.

[39] Rahdari, P. and Hoseini, S. M., 2012. "Drought stress: a review." *Intl. J. Agron Plant Prod*, vol. 3, pp. 443–6.

[40] Purwanto, E. D. I., Samanhudi, S., and Effendi, Y., 2017. "Response of some upland rice varieties to drought stress examined using Polyethylene Glycol and water applications." *International Journal of Tropical Drylands*, vol. 1, pp. 69-77.

[41] Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P. C., and Sohrabi, E., 2010. "Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars." *Australian Journal of Crop Science*, vol. 4, pp. 580-585.

[42] Salehi-lisar, S. Y., Motafakkerazad, R., Hossain, M. M., and Rahman, I. M. M., 2012. "Water stress in plants: causes, effects and responses, water stress. In: Ismail Md. Mofizur Rahman editor. InTech."

[43] Zu, X., Lu, Y., Wang, Q., Chu, P., Miao, W., Wang, H., and La, H., 2017. "A new method for evaluating the drought tolerance of upland rice cultivars." *The Crop Journal*, vol. 5, pp. 488-498.

[44] Yang, X., Wang, B., Chen, L., Li, P., and Cao, C., 2019. "The different influences of drought stress at the flowering stage on rice physiological traits, grain yield, and quality." *Scientific Reports*, vol. 9, pp. 1-12.

[45] Ullah, H., Datta, A., Shrestha, S., and Ud Din, S., 2017. "The effects of cultivation methods and water regimes on root systems of drought-tolerant (RD6) and drought-sensitive (RD10) rice varieties of Thailand." *Archives of Agronomy and Soil Science*, vol. 63, pp. 1198-1209.

[46] Hazman, M. and Brown, K. M., 2018. "Progressive drought alters architectural and anatomical traits of rice roots." *Rice*, vol. 11, pp. 1-16.

[47] Kim, Y., Chung, Y. S., Lee, E., Tripathi, P., Heo, S., and Kim, K. H., 2020. "Root response to drought stress in rice (*Oryza sativa* L.)." *International Journal of Molecular Sciences*, vol. 21, p. 1513.

[48] Nazirah, L., Purba, E., Chairani, H., and Rauf, A., 2018. "Effect of soil tillage and mycorrhiza application on growth and yields of upland rice in drought condition." *Asian J. Agri. and Biol.*, vol. 6, pp. 251-258.

[49] Gowda, V. R., Henry, A., Yamauchi, A., Shashidhar, H. E., and Serraj, R., 2011. "Root biology and genetic improvement for drought avoidance in rice." *Field Crops Research*, vol. 122, pp. 1-13.

[50] Basu, S., Ramegowda, V., Kumar, A., and Pereira, A., 2016. Plant adaptation to drought stress. F1000Research, 5.