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Research Article

Performance of sorghum varieties with various fertilizer doses in peatlands of West Aceh Regency

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ABSTRACT

West Aceh Regency is one of the regions in Indonesia with quite extensive peatlands, but the diversity of food crop commodities is still very low. To enhance food diversification programs of rice, sorghum production is important. The purpose of this research was to test several varieties of sorghum in the peatlands of West Aceh Regency. This research was carried out from July to November 2023. Several new varieties of sorghum released by the Indonesian Cereals Research Institute (ICERI) were evaluated in the peatland of West Aceh. The research method used a randomized complete block design (RCBD) with two factors and three replications. The first factor was different varieties of sorghum, and the second factor was various doses of fertilizers. The varieties used were Soper 7 Agritan, Bioguma 1, and Suri 3. The doses used Control (no treatment), Dose I (75 kg Urea ha^{-1} + 50 kg SP-36 ha^{-1} + 50 kg KCl ha^{-1}), Dose II (150 kg Urea ha^{-1} + 100 kg SP-36 ha^{-1} + 100 kg KCl ha^{-1}), and Dose III (225 kg Urea ha^{-1} + 150 kg SP-36 ha^{-1} + 150 kg KCl ha^{-1}). The results showed that the Bioguma 1 variety adapted better than the other varieties, where the plant height was 187.97 cm, the number of leaves was 15.08, the panicle diameter was 35.92 mm, and the panicle weight was 79.52 g. Meanwhile, fertilizer dose II is better on the character of the number of leaves and panicle length. The interaction effect between the two factors only showed a significant influence on panicle length. Therefore, the Bioguma 1 sorghum variety can be a recommended variety for planting in the shallow peatlands of West Aceh.

Keywords: Acidic soil; alternative food; food diversification

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INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is a cereal crop that has the potential to be developed in Indonesia due to agroecological conditions, land availability, wide climatic adaptation, and drought tolerance (Dossou-Aminon et al., 2015). Sorghum can be used as an alternative food substitute for rice and wheat because it is rich in carbohydrates (87.87%), protein (8.81%), and fat (1.97%). This content may vary depending on the variety (Andriani et al., 2019). Sorghum has unique nutritional content, is gluten-free, and is suitable for people with celiac disease. Sorghum bread is the best formulation for gluten-free bread compared to wheat (de Oliveira et al., 2022).

Aceh Province has a peat area of 274,051 ha, of which 105,417 ha (38.40%) is spread on the coast of West Aceh Regency, while the rest is spread in South Aceh Regency, covering an area of 168,634 ha (61.60%) (Setyowati et al., 2017). Peatlands in West Aceh Regency include shallow peat with a peat thickness of 60–100 cm, low soil fertility conditions, and pH 4.5, which is categorized as very acidic soil (Ritung et al., 2007). Peatland variability is very high, both in terms of peat thickness, maturity, and fertility. Not all peatlands are suitable for agricultural use, and peatlands that can be used for food crops are recommended on shallow peat < 100 cm (Hadianto et al., 2018).

One of the adaptive plants cultivated on peatlands is the sorghum (Lestari & Andrian, 2017). Sorghum in Indonesia has long been cultivated, but its use as food, feed, and industry is still very limited. Its utilization in Aceh Province, especially in West Aceh Regency, is also relatively low, but the area of peatland to be used as agricultural land is quite large. This condition is because peatlands have limiting factors, including acidic soil, nutrients, and low fertility levels, therefore the land fertility does not support plant growth of common commodities like rice. To overcome these limiting factors, it is necessary to add fertilizer to improve land conditions to be good for sorghum growth.

One of the fertilizers that can be used to increase peatland fertility is inorganic fertilizer. Inorganic fertilizers contain one or more inorganic compounds with a certain nutrient content. The fertilizers used in this study were Urea, SP-36, and KCl fertilizer. The addition of a compound 300 kg NPK ha^{-1} provides the highest growth and yield on coastal lands (Susilo et al., 2021).

This research aimed to utilize peatlands in the West Aceh region to produce more diverse food production commodities, and apply productive land and appropriate technology. One of the approaches to be used in this research is to use various varieties of the latest sorghum released by the Balitcereal Agency, Maros Ministry of Agriculture. This latest variety will be tested to determine whether there are new adaptive and viable sorghum varieties on peatlands, obtain the right level of fertilization dose to increase the growth of sorghum plants, and obtain interactions between sorghum varieties and fertilizer doses that can be recommended on peatlands. The *state of the art* in this study is a follow-up study on new varieties that have been released by the Indonesian Cereals Research Institute (ICERI), the Ministry of Agriculture on marginal land (peatlands) on a wider scale.

MATERIALS AND METHODS

Location and experimental design

The research was conducted at University Farm at Teuku Umar University, West Aceh Regency. This research was carried out from July to November 2023 on the peatland of Teuku Umar University Farm, West Aceh. The experimental materials were sorghum seeds obtained from the Indonesian Cereals Research Institute (ICERI), South Sulawesi Province. The research was conducted using a two-factor randomized complete block design (RCBD). The first factor in treatment was three varieties of sorghum, and the second factor was the dose of fertilization on peatlands. The first factor consisted of three national varieties, namely Soper 7 Agritan, Bioguma 1, and Suri 3. The varieties to be tested were new varieties that had never been tested in West Aceh Regency. Fertilization treatments included control (no treatment), dose I (75 kg Urea ha^{-1} + 50 kg SP-36 ha^{-1} + 50 kg KCl ha^{-1}), dose II (150 kg Urea ha^{-1} + 100 kg SP-36 ha^{-1} + 100 kg KCl ha^{-1}), and dose III (225 kg Urea ha^{-1} + 150 kg SP-36 ha^{-1} + 150 kg KCl ha^{-1}). There were 12 treatment combinations with three repetitions. The total of experimental units was 36 plots. Each varietal treatment was planted in each experimental unit with as many as 30 plants, and in each experimental unit, there were 10 plants used as measurement samples.

Cultivation method

The land was processed using a tractor, and then a raised bed was formed with a size of 3.75 m x 0.9 m for 36 units. The distance between beds was 0.5 m, and the distance between the repetitions was one meter. Sorghum seeds were planted with a planting distance of 75 cm x 15 cm two seeds per planting hole. Replanting is carried out one week after planting (WAP). Thinning was done at two weeks after planting by leaving one plant with the highest vigor in each planting hole.

All dose of KCl, SP-36 fertilizer, and 2/3 dose of urea according to the treatment level was applied at planting time. The remaining 1/3 dose of urea was given at 4 WAP. Fertilizer application was carried out in side dressing, with a distance of ± 10 cm from the planting hole. Plant maintenance included thinning, weeding, pest control, and harvesting.

Weeding was carried out regularly plants. Sorghum panicle covering was carried out at the time of panicle filling to protect from bird attack. Pest control of plant diseases was implemented using insecticides of carbofuran and deltamethrin and fungicides of propineb (Andriani et al., 2023).

Observations and data analysis

Observations of growth and yield variables included the field vigor (%), plant height (cm), number of leaves (strands), stem diameter (mm), flowering age (days), harvest age (days), panicle length (cm), panicle diameter (cm), and panicle weight (g). Data analysis was carried out with the analysis of variance (ANOVA), and if the treatment effect was significant, the Fisher's LSD test at 5% level was performed. The data was analyzed by Minitab 17 Statistical Software. Soil analysis is in the form of preliminary soil analysis, which is tested at the Laboratory of PT. Nusa Pusaka Kencana Asian Agri.

RESULTS AND DISCUSSION

Shallow peat has a relatively higher fertility rate and has lower environmental risks than deep peat (Surahman et al., 2017). Peatlands with a depth of 1.4-2 m are classified as suitable (suitability class S3) for various types of food crops (Hadianto et al., 2018). Based on climate data obtained from the Meteorology, Climatology, and Geophysics Agency of the West Aceh Climatology Station, the research was carried out in the rainy season, with the amount of monthly rainfall ranging from 336 mm, temperature ranging from 22-30 °C, and air humidity ranging from 75-95%.

Sorghum plants are generally cultivated at temperatures of 23-34 °C, annual rainfall of 600-2,000 mm, air humidity of 75-85%, and a good soil pH range of 5.5-7.5 (Susilo et al., 2023). However, conditions during the study showed that rainfall (>200 mm) and air humidity (>85%) were relatively high for sorghum growth. The results of soil analysis showed low fertility with an N content of only 0.25%, pH 4.67 very acidic, and CEC 3.95 C mol kg^{-1} very low (Table 1). Low N-total content, low organic matter, and acidic pH inhibit the activity of microorganisms for decomposition and fixing N (Rosmalinda & Susanto, 2018). The CEC value of soil is dependent on the pH value; in pH below neutral, the CEC of the soil will be low (Ardiansyah et al., 2022).

Table 1. Results of preliminary soil analysis at the research site.

Test parameters	Unit	Value	Description
pH (H_2O)	-	4.67	Very acid
C-Organic	%	3.76	High
N	%	0.25	Medium
C/N	-	15.04	High
P total	mg P_2O_5 $100g^{-1}$	214.88	Very high
K total	mg K_2O $100g^{-1}$	91.57	Very high
CEC	C mol kg^{-1}	3.95	Very low

Analysis of variance

The results of the analysis of variance showed that the treatment of various varieties of sorghum had a significant effect on all observations, except for harvest age and panicle length. Similarly, in the treatment of various fertilizer doses, there was only a significant effect on the number of leaves and panicle length. The interaction between variety and fertilizer dose only had a significant effect on panicle length (Table 2). Each variety had different growth abilities. Soper 7 Agritan, Bioguma 1, and Suri 3 varieties adapted well to land conditions with low nutrient availability in the peatlands of West Aceh. However, increasing the maximum fertilizer dose to 225 kg Urea ha^{-1} + 150 kg SP-36 ha^{-1} + 150 kg KCl ha^{-1} had no effect on sorghum growth. This condition shows that high fertilizer doses are not able to provide nutrients that can be absorbed by plants. This is due to limiting factors in peatlands such as acid pH, soil nutrients and soil fertility levels are low.

Table 2. Summary of analysis of variance of sorghum varieties, fertilization, and its interactions

Observations characters	First factor (Varieties)		Second factor (Fertilizing dose)		Interaction (Variety*Fertilization)	
	Mean square	p-value	Mean square	p-value	Mean square	p-value
Vigor	1265.25	0.00**	15.66	0.32ns	12.66	0.45ns
Plant height	1614.30	0.03*	242.60	0.62ns	220.80	0.76ns
Stem diameter	22.64	0.01**	1.48	0.79ns	2.83	0.68ns
Number of leaves	21.94	0.02*	3.95	0.01**	0.50	0.72ns
Flowering age	56.65	0.03*	4.12	0.56ns	4.01	0.67ns
Harvest age	88.36	0.13ns	68.92	0.18ns	25.69	0.69ns
Panicle length	9.31	0.10ns	15.32	0.02*	10.39	0.03*
Panicle diameter	33.85	0.02*	11.46	0.20ns	4.54	0.67ns
Panicle weight	1584.60	0.01**	196.70	0.36ns	305.20	0.16ns

Note: ** significant at p<0.01, * significant at p<0.05 and ns = not significant

Plant performance

Fisher's LSD test results showed that the median value of the Suri 3 variety had the highest vigor of 96.00% and was significantly different from the Soper 7 Agritan variety and the Bioguma 1 variety which had a growth capacity of around 77.00% -79.75% (Table 3). Vigor with various doses of urea, SP-36, and KCl fertilizers was also not significantly different (Table 4). The growing power of the Suri 3 variety is higher than that of other varieties, this is suspected of both external and internal factors. Internal factors are the genetic characteristics of the variety, while external factor is the tolerant nature of the variety to the growing environment such as minimal nutrient availability, changes in temperature, humidity, rainfall, and sunlight intensity (Andayani, 2020).

Table 3. Average value and LSD test of sorghum varieties.

Characters	Sorghum varieties		
	Variety 1 (Soper 7 Agritan)	Variety 2 (Bioguma 1)	Variety 3 (Suri 3)
Vigor (%)	79.75b	77.00b	96.00a
Plant height (cm)	173.86ab	187.97a	165.01b
Stem diameter (mm)	14.75b	15.08b	17.28a
Number of leaves (strands)	10.63b	12.94a	10.58b
Flowering age (days)	62.31a	62.82a	58.83b
Harvest age (days)	110.42a	108.01ab	105.00b
Panicle length (cm)	19.11ab	20.19a	18.43b
Panicle diameter (mm)	34.01a	35.92a	32.67b
Panicle weight (g)	74.58a	79.52a	57.60b

Note: Values followed by the same letter in the same row indicate no significant difference in the LSD test at 5% level.

The plant height of Bioguma 1 variety was 187.97 cm, the highest compared to Soper 7 Agritan and Suri 3 varieties, which were 173.86 cm and 165.01 cm, respectively (Table 3). Treatment with various doses of fertilization also had no significant difference and ranged from 169.20 - 181.13 cm (Table 4). The plant height growth of the three varieties was lower than in the description of the varieties. Based on the description of the plant height varieties Bioguma 1, Soper 7 Agritan, and Suri 3 are classified as tall with 266 cm, 281 cm, and 239 cm, respectively. This condition shows that planting sorghum in peatlands of Aceh suppressed the plant height of all varieties. The differences in genetic characteristics of each sorghum variety cause differences in responsiveness to environmental conditions and can undergo physiological and morphological changes in a direction appropriate to the new environment (Ariefin et al., 2022).

It is probable that different plant height in the present experiment with released variety description from the government is influenced by a high C/N ratio in the soil causes low N-availability. Here, peat soil generally has a high C/N ratio (Table 1). The same result was obtained by Manurung et al. (2016) the height of plants in upland rice (gogo) is not in accordance with the variety description because the C-organic and N-total content are high, while the high N-total content is likely not to be followed by a high availability of N for plants, which is reflected in the value of the C/N ratio. A high C/N ratio causes the N produced in the mineralization process to be immobilized by microorganisms for their needs, so it is not available to plants.

Table 4. Average value of sorghum varieties by different fertilizer doses.

Characters	Doses of fertilizers			
	No treatment	Fertilization dose 1	Fertilization dose 2	Fertilization dose 3
Vigor (%)	82.55a	84.33a	84.33a	85.77a
Plant height (cm)	173.80a	169.20a	178.08a	181.13a
Stem diameter (mm)	15.48a	15.44a	16.31a	15.60a
Number of leaves (strands)	12.32ab	11.74bc	12.82a	11.31c
Flowering age (days)	62.25a	60.86a	60.79a	61.38a
Harvest age (days)	111.11a	108.44ab	104.44b	107.22ab
Panicle length (cm)	18.64b	19.27a	21.05a	18.03b
Panicle diameter (mm)	34.92a	32.85a	35.00a	35.20a
Panicle weight (g)	66.00a	72.12a	76.40a	67.65a

Note: Values followed by the same letter in the same row indicate no significant difference in the LSD test at 5% level.

The largest stem diameter Suri 3 variety was 17.28 mm (Table 3). The stem diameter treated with various doses of fertilization ranged from 15.44 to 16.31 mm (Table 4). The stem diameter in this research was lower than in research by Pamungkas et al. (2021) in the area of post-mining of tin. It showed that the Suri 3 variety adapted to peatlands, but the growth of stem diameter was not optimal. The insignificant growth of sorghum stem diameter was probably influenced by high rainfall during the experiment, resulting in the leaching of KCl nutrients as an important nutrient for division and cell enlargement of the stem (Ismuhadi, 2022). Sriagtula and Sowmen (2018) also stated that at an acidic pH nutrient deficiencies often occur, especially P, Ca, Mg, N, and K causing low performance of the stem diameter of sorghum.

The variety with the highest number of leaves was Bioguma varieties 1 to 13 strands (Table 3). The number of leaves treated with various doses of fertilization ranged from 11.31 - 12.82 (Table 4). The difference in the number of leaves in each variety was because each variety has a different response to fertilization. Plants from fertilization dose II with 150 kg Urea ha^{-1} + 100 kg SP-36 ha^{-1} + 100 kg KCl ha^{-1} produced the highest number of leaves, up to 12.81. It is probable that low phosphorus availability occurred not only in P-poor soils but also in P-rich due to the chelating effect. Based on Sitepu et al. (2015) phosphorus affects new cells for leaf growth, and fertilization 95 kg SP-36 ha^{-1} is enough to support the growth of the maximum number of leaves in sorghum.

The flowering age and harvest age of the Suri 3 variety were faster than the other two varieties. Flowering age ranged from 104-111 days (Table 4). There are no significant differences in flowering age and harvest age in the three varieties with the official variety descriptions. The flowering age and harvest age of the plant depend on the genetic factors of the variety and environmental factors. According to Marlina et al. (2020), each variety has a different response to N and P fertilizers application; at the flowering time, the plant absorbs N in considerable quantities resulting in the delaying of flowering stages.

The length of panicles in the three varieties showed no significant difference, with middle values ranging from 18.43-20.19 cm, while panicle diameters ranged from 32.67-35.92 mm (Table 3). This research shows that the panicle diameter determines the difference between varieties, the larger the panicle diameter greater the potential to

produce more seeds. However, treatment with various fertilizer doses did not provide significant differences in panicle length and panicle diameter. This is due to soil acidity which is related to the availability of P nutrients. P nutrients added to acidic soils will undergo a transformation process into Al-P and Fe-P forms. These P forms are relatively insoluble in the soil, thus the availability of P nutrients in acidic soils is relatively low, thus becoming a limiting factor for the breakdown of carbohydrates into energy in metabolic processes for plant growth and yield (Marlina et al., 2020). Sihaloho and Situmeang (2021) stated that 90% of the P nutrient is absorbed by cereal plants during the generative and seed formation phases.

The highest panicle weight was Bioguma 1 variety (79.52 g), and it was not significantly different from Soper 7 Agritan (74.58 g), while Suri 3 variety had the lowest panicle weight of 57.60 g (Table 3). The treatment dose of fertilization was also not significantly different, with the middle value ranging from 66.00-76.40 g (Table 4). It seems that the difference in panicle weight is due to genetic factors. In the present experiment, the absence of differences between fertilization doses is likely due to the lack of available nutrients in peatlands. It is in line with results obtained by Kurniasari et al. (2023) application of manure and biological fertilizers to sorghum was no different. In case of insufficient nitrogen and phosphorus absorption during seed filling, there will be a translocation of nutrients from leaves to seeds, which causes leaf chlorosis and disturbance in photosynthetic activities.

The weight of panicles In Bioguma 1 and Soper 7 Agritan varieties is smaller than the research by Wibawa et al. (2021) and Rahman et al. (2022) while and Suri 3 variety is smaller than the research by Ariefin et al. (2022). The growth of several varieties of sorghum on peatlands with high rainfall (>200 mm) is one of the main factors that influence the difference in response of each variety. According to Ruminta et al. (2017), the yield of sorghum seeds depends on environmental conditions. During the ripening stage of sorghum seeds, plants require dry environmental conditions to obtain good quality. Dry environmental conditions will encourage the seed ripening process to be faster and the seed shape to be more uniform.

Table 5. Growth and yield characters of different sorghum varieties and fertilizer doses.

Treatment	VG	PH	SD	NL	FA	HA	PL	PD	PW
V1P0	78.00bc	163.62abc	14.56b	12.25abc	62.52ab	113.33a	19.60bc	35.01abc	71.01abcd
V1P1	80.67b	147.55abc	14.98ab	10.97cd	62.30ab	111.66ab	20.92ab	32.17bc	73.52abcd
V1P2	80.33b	166.71abc	15.03ab	12.62ab	61.37abc	106.66ab	19.15bc	36.52ab	87.20a
V1P3	80.00bc	156.88abc	14.46b	10.67d	63.05a	110.00ab	18.78c	36.36ab	65.32bcd
V2P0	76.33bc	173.77ab	14.92b	12.88ab	62.91a	113.66a	19.07bc	36.49ab	84.61abc
V2P1	77.67bc	172.73ab	14.65b	13.25ab	62.27ab	105.00ab	19.74bc	35.01abc	72.69abcd
V2P2	74.00c	165.53abc	16.88ab	13.44a	62.33ab	103.33ab	23.98a	37.15a	86.33ab
V2P3	80.00bc	179.84a	13.86b	12.20abc	63.77a	110.00ab	17.93bc	35.04abc	74.43abcd
V3P0	93.33a	139.00c	16.98ab	11.83bcd	61.33abc	106.33ab	17.25c	33.27abc	42.39e
V3P1	94.67a	142.33bc	16.67ab	11.01cd	58.00c	108.66ab	17.16c	31.38c	56.50de
V3P2	98.67a	157.00abc	17.01ab	12.41abc	58.66bc	103.33ab	20.00bc	31.86c	68.25abcd
V3P3	97.33a	161.66abc	18.47a	11.05cd	57.33c	101.66b	19.33bc	34.17abc	63.20cde

Note: The average followed by the same letter showed no significantly different interaction in the LSD Test level of 5%. V1 = Soper 7 Agritan, V2 = Bioguma 1, V3 = Suri 3. P0 = No fertilizer, P1 = Fertilizer dose I, P2 = Fertilizer dose II, P3 = Fertilizer dose III. VG = Vigor (%), PH = Plant height (cm), SD = Stem diameter (mm), NL = Number of leaves, FA = Flowering age (days), HA = Harvest age (days), PL = Panicle length (cm), PD = Panicle diameter (mm), PW = Panicle weight (g).

The interactions between sorghum varieties and fertilizers were not significantly different in all observed characters except for panicle length. The best sorghum panicle length was the Bioguma 1 variety, which was 23.98 cm with a second dose of fertilizer, namely 150 kg Urea ha^{-1} + 100 kg SP-36 ha^{-1} + 100 kg KCl ha^{-1} (Table 5). The fertilizer dose is in accordance with the recommendations for fertilization for sorghum plants, which means that additional fertilizer doses as in the third treatment have no effect on the growth and development of sorghum. According to Ahadiyat et al. (2023), intensive

fertilization is not necessarily able to increase panicle weight in barley cereals. This is due to factors changing the intensity of rain which tends to increase, resulting in a high risk of damage and loss due to inundation stress.

Overall, the Bioguma 1 variety gave quite good results, where characteristics such as plant height, number of leaves, flowering age, panicle length, and panicle diameter are provided; thus considered suitable for growing in the peatlands of West Aceh. The insignificance effect of NPK fertilizer application needs further research to understand the complex system of nutrient availability in peatlands. Low nutrient availability in the soil inhibits plant growth performance and plant biomass (Suminar et al., 2017). Application of soil amendments such as using limestone and soil conditioner might useful research focus to increase sorghum production in peatlands of West Aceh.

CONCLUSIONS

Sorghum varieties exhibited different responses on vigor, plant height, stem diameter, number of leaves, flowering age, panicle diameter, and panicle weight. The Bioguma 1 variety exhibited superior growth in peatland as compared to Soper 7 Agritan and Suri 3 with plant height of 187.97 cm, number of leaves of 15.08 cm, panicle diameter of 35.92 cm, and panicle weight of 79.52 g. On the other side, the largest stem diameter and faster flowering age were shown by Soper 7 Agritan variety, i.e., 17.28 mm and 58.83 days, respectively. Fertilizer doses had a significant effect on the number of leaves, where at dose II the number of leaves was 12.82 strands more than other varieties. Besides that, the interaction between the Bioguma 1 variety and fertilization dose II (V2P2) was significant in the leaf number.

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