Growth Perfomance and Yield of Two Bioguma Sorghum Varieties Cultivated During the Rainy Season

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Research Note

Growth Performance and Yield of Two Bioguma Sorghum Varieties Cultivated During the Rainy Season

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Abstract

Sorghum is a cereal crop with significant potential, considering its benefits as a food, feed, or bioethanol source. Aside from being a drought-tolerant plant, sorghum can grow in different land conditions, with varieties Bioguma 1 and 2 considered to have high yield potential. Therefore, this study aimed to assess the growth and yield of these 2 sorghum varieties using a randomized block design with 3 replicates. The results showed that Bioguma 1 had a significantly better growth performance and produced a higher yield compared with Bioguma 2. Considering its higher disease resistance, growth, and yield, Bioguma 1 could be used as the mother plant for a ratoon system. This ratoon system would allow sorghum to be harvested twice a year, requires fewer inputs, and shortens the second harvest period.

Keywords: Bioguma, production, sorghum, yield

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is a tropical cereal crop native to Ethiopia in East Africa and thrives in arid environments. It belongs to the Poaceae family and has a morphology similar to corn. It is also known for its versatility, as nearly all of its parts can be utilized. The grains are consumed (Stefoska-Needham 2015; Xiong et al 2019; Xu et al 2021), the stems are used as a source of raw materials for the bioethanol industry (Suryaningsih and Irhas 2014; Xiao et al 2021; Frankowski et al 2022), and the leaves can be fed to livestock (Etuk et al 2012; Tegegn et al 2021).

Generally, sorghum is easily adaptable for cultivation in tropical areas and is classified as a C_4 plant, which is known for its efficiency in carrying out the photosynthesis process. This plant is also relatively tolerant to drought (Abdel-Ghany et al 2020; Abreha et al 2022) and high salinity (Mansour et al 2021; Dourado et al 2022). It also has a fairly short harvest period of around 3 to 4 mo with water requirements of 4,000 m^3 per season, which is significantly less than the requirements for corn and sugarcane, estimated at 8,000 m^3 and 36,000 m^3, respectively (A'ayuni et al 2021).

Given these significant benefits, there is great potential for sorghum development in Indonesia. However, sorghum is still perceived as a crop with low economic value, and the cultivation is carried out inefficiently (Subagio and Aqil 2013). The plant is only grown in a few regions, including Java, South Sulawesi, Southeast Sulawesi, East Nusa Tenggara, and West Nusa Tenggara, compared with other cereal crops such as rice and corn (Slameto 2022). Similarly, in South Sumatra, a province with extensive wetlands and an adequate water supply, sorghum cultivation is relatively uncommon as the plant is considered a dryland crop.

The use of superior varieties is crucial to enhancing sorghum productivity. Genetic components and the growing environment, such as soil quality, water availability, and plant management, play a significant role in determining plant yield. By the end of 2022, 27 sorghum varieties were released by the Indonesian Ministry of Agriculture. These include Super 6, 7, and 9 Agritan; Bioguma 1, 2, and 3 Agritan; EPL1; Suri 3 and 4 Agritan; Samurai 1 and 2; Super 1 and 2; Pahat; Kawali; Numbu;

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Sangkur; Mandau; Badik; Keris; KD.4; UPCA Si and S2; Cempaka; Katenggu; Dorga; Bird Prof; No. 6C, 7C, 46, 72; and Hegaria (Office of the Department of Agriculture and Food Security of the Special Region of Yogyakarta 2023). Bioguma varieties have a high yield potential of 9.3 t ha^{-1}. The sugar brix in the stem can reach up to 15%, with a sap volume of 122 mL (Zuhriyah and Priyanto 2024). However, the morphology and yield of local and superior sorghum varieties still differ (Sulistyawati et al 2019) due to agroclimatic factors. The ability of Bioguma varieties 1 and 2 to be planted in dry and acidic soils has not been extensively studied, necessitating further research on growth and yield in these conditions.

To reduce production costs, an efficient solution is to implement the ratooning method. Ratooning sorghum is expected to produce 2 harvests, with the planting time shifted to February for the rainy season and to June for the dry season. However, shifts in planting seasons can make sorghum vulnerable to extreme drought and pest and disease management in stressed conditions. The yield of ratoon sorghum is highly dependent on the morphological characteristics of the mother plants. According to Paesal et al (2021), these indicators include plant height, number of leaves, canopy dry weight, and grain weight. Therefore, this study was conducted to examine the growth characteristics and yield of Bioguma sorghum varieties planted during the rainy season in the second season. Information on ratoon characteristics due to the effect of the planting season was also obtained. The results of this study can be used as baseline information for developing sorghum in dryland conditions as a second planting season, with 2 harvests per season.

Materials and Methods

The experiment was conducted in the research field of the Faculty of Agriculture, Universitas Sriwijaya, in Indralaya, South Sumatra, Indonesia (3°13′20.8″S, 104°38′47.0″E) from October 2022 until January 2023. This study used a randomized block design. Sorghum plants from the Bioguma 1 and Bioguma 2 varieties were planted in 2 different plots with a size of 40 × 4 m each, positioned side by side at a distance of about 5 m. The seeds were then planted with a planting space of 25 × 75 cm, resulting in a total of 5 rows of sorghum plants per plot. Data were gathered in the 3 middle rows of sorghum in each treatment plot, and each replicate consisted of 10 sample plants. Before planting, the plots were treated with 32 kg (2 t ha^{-1}) of lime and 150 kg (10 t ha^{-1}) of chicken manure. Fertilizers were also applied to the plants in the form of urea (200 kg ha^{-1}), triple superphosphate (TSP) (100 kg ha^{-1}), and potassium chloride (KCl) (50 kg ha^{-1}).

Monitoring and measurement were carried out for the sample plants at the end of the research or 16 wk after planting (WAP). Parameters observed were plant height (cm), leaf number, root number, leaf dry weight (g), stem dry weight (g), root dry weight (g), panicle weight (g), filled grain per panicle (g), empty panicle weight (g), and thousand grain weight (g).

Plant disease occurrence was also recorded based on the symptoms observed. The percentage damage was calculated based on the number of plants affected divided by the total population (Herdiana 2010). Data collected were summarized and analyzed using a *t*-test and Pearson product-moment correlation among characteristics using IBM SPSS Statistics (Version 29.0.2.0).

Results and Discussion

Growing Environment and Disease Resistance

During the rainy season, both Bioguma 1 and Bioguma 2 varieties were grown on cambisol soil with a pH of 5.1. Based on information from the climate station (Fig. 1), there was roughly 360.5 mm of precipitation per month with an average temperature of 27°C and 88% relative humidity during the trial period (October 2022 to January 2023), indicating that the sorghum plants had adequate water sources during the growth period.

Upon observation of plant disease symptoms (Table 1), several plants from both varieties of sorghum were found to have leaf rust and stem rot, with Bioguma 2 having more damage than Bioguma 1. However, neither of the varieties exhibited anthracnose. This result is consistent with the descriptions of Bioguma 1 and 2 varieties, which were recorded to have resistance to both stem rot and leaf rust diseases (Office of the Department of Agriculture and Food Security of the Special Region of Yogyakarta 2023).

Agronomic and Yield Characteristics

Based on the *t*-test results, Bioguma 1 had significantly better agronomic performance compared with Bioguma 2 in terms of plant height, leaf number, and dry weight (Table 2). In sorghum ratoon farming, vegetative traits like plant height and leaf number are beneficial when selecting mother plants. According to Atumo and Mengesha (2022), ratoon crop biomass correlated positively with plant height, tiller number, leaf number, leaf length, and leaf width. This finding suggests that increased ratoon sorghum yield could be achieved by selecting for any of these vegetative characteristics. In addition, Bioguma 1 was observed to be a more suitable sorghum variety for mother plants in ratoon farming than Bioguma 2 due to better vegetative characteristics.

Results also show no significant variation in root number between the 2 sorghum varieties. Water availability has been reported as the main factor of differences in root development (De Bauw et al 2019; Liu and Sun 2020). Given that both varieties were grown in the same soil and water conditions, there was

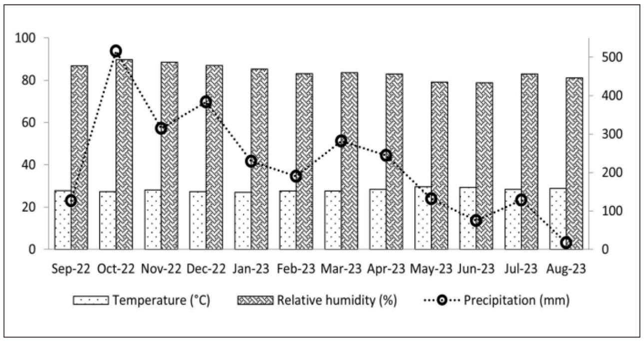

Figure 1 Temperature, relative humidity, and precipitation in the research field of the Faculty of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia from September 2022 to August 2023. (Adapted from BMKG 2023)

Table 1 Percent damage (%) of the studied Bioguma 1 and 2 sorghum varieties

Varieties	Percent damage (%)			Damage rating		
	Puccinia purpurea	*Fusarium spp.*	*Colletotrichum sublineola*	*Puccinia purpurea*	*Fusarium spp.*	*Colletotrichum sublineola*
Bioguma 1	2.65	0.10	ND	Low	Low	ND
Bioguma 2	5.69	0.81	ND	Low	Low	ND

Note: ND—No Data

no significant difference in the number of roots. Values for the stem and leaf dry weight of Bioguma 1 were higher than those of Bioguma 2 due to significant differences in plant height and leaf number. Leaf number tends to increase following a rise in plant height, which consequently affects dry weight. A significant correlation was also observed between plant height and leaf number, with Bioguma 1 having more leaves than Bioguma 2 due to its greater plant height. Based on the results, the appearance of vegetative organs, including plant height, is likely to influence the number of leaves and stem diameter, as also stated by Sulistyawati et al (2019). Characteristics of the studied plant varieties, such as morphological appearance and panicles, were also observed (Fig. 2).

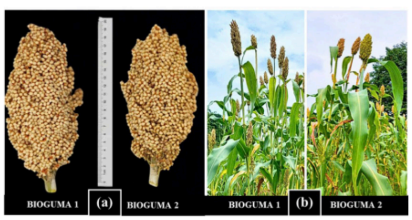

Figure 2 Panicles (a) and stems (b) of the studied Bioguma 1 and 2 sorghum varieties.

Similar results were observed in yield components, with Bioguma 1 having higher panicle weight and filled grain per panicle but lower empty grain weight per panicle (Table 2). The percentage distribution of dry weight components was also estimated from all plant parts (Fig. 3). The results showed that the Bioguma 1 variety had a lower proportion of vegetative parts, including roots, stems, and leaves, compared with Bioguma 2. In contrast, Bioguma 1 produced more grains per plant, higher biomass, and a greater proportion of grain yield. The quantity and weight of grains produced are significantly influenced by the rate of photosynthate assimilation and carbohydrate translocation from reserve pools in vegetative organs during the grain-filling stage (Shirdelmoghanloo et al 2022; Teng et al 2023).

The size of the resulting grains directly affects the thousand grain weight; for instance, larger grains will result in a greater thousand grain weight. In this study, no significant variations were observed between the 2 varieties, indicating that the grain sizes of both varieties were relatively similar. Grain size is a significant factor in cereal crop output, which mostly depends on the genetic potential and grain-filling ability of a genotype (Tao et al 2020).

This study also found a significant correlation between grain weight and stem and leaf dry weight (Table 3). The increase in grain weight was affected by a rise in stem and leaf dry weight. This is due to the translocation of accumulated

Table 2 Agronomic and yield characteristics components of the studied Bioguma 1 and 2 sorghum varieties

Parameters	Varieties		*t*-value
	Bioguma 1	Bioguma 2	
Growth Parameters			
Plant height (cm)	214.00 ± 13.43	126.01 ± 5.69	3.37*
Leaf number	14.55 ± 1.52	8.33 ± 1.14	4.08*
Root number	19.80 ± 1.92	14.57 ± 5.72	0.34
Leaf dry weight (g)	17.62 ± 3.24	13.07 ± 3.93	5.17*
Stem dry weight (g)	66.80 ± 11.81	59.54 ± 3.05	2.64*
Root dry weight (g)	25.10 ± 7.52	18.00 ± 3.41	3.18*
Yield Parameters			
Panicle weight (g)	132.20 ± 13.93	110.70 ± 6.03	8.92*
Filled grain per panicle (g)	115.30 ± 18.11	83.89 ± 17.58	9.04*
Empty panicle weight (g)	17.9 ± 2.43	26.81 ± 2.16	3.98*
Thousand grain weight (g)	26.41 ± 5.72	25.70 ± 7.39	0.85
$t_{0.05}$ = 1.68			

Data represent mean and standard deviation. Values followed by (*) indicate a significant difference at $t_{0.05}$

carbohydrates in both stems and leaves during the grain-filling period. Previous research has also reported similar results (Song et al 2018; Veenstra et al 2023).

Based on the data collected, the yield of both Bioguma 1 and 2 sorghum varieties was calculated. The estimated yield of Bioguma 1 was about 6.1 t ha^{-1}, which was higher than Bioguma 2 at 4.5 t ha^{-1}. However, this result is lower compared with the variety descriptions of Bioguma 1 and 2, where the average yield is estimated to be around 7 t ha^{-1} and the potential yield up to 9.2 t ha^{-1}. The lower yield may have been caused by the smaller grain size. In this study, Bioguma 1 and 2 could only produce 26.41 and 25.70 g of thousand grain weight, respectively, despite previous reports estimating an average of 32.7 g of thousand grain weight. The appearance of the generative organs was relatively the same as local varieties with the local sorghum genotypes in East Java Province, Indonesia, namely Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1),

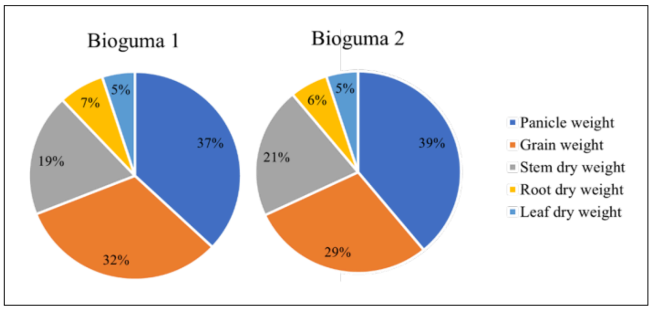

Figure 3 Dry weight proportion of the studied Bioguma 1 and 2 sorghum varieties.

Table 3 Association among parameters observed in the studied Bioguma 1 and 2 sorghum varieties

	PH	LN	RN	PW	GW	EPW	RDW	SDW	LDW
LDW	0.276	−0.022	0.042	0.542**	0.547**	0.297	−0.038	0.348	ND
SDW	0.231	0.294	0.271	0.393*	0.400*	0.197	0.209	ND	
RDW	0.307	0.530**	0.397*	0.366*	0.358	0.272	ND		
EPW	0.076	0.260	0.030	0.654**	0.560**	ND			
GW	0.244	0.337	−0.091	0.993**	ND				
PW	0.234	0.345	−0.079	ND					
RN	0.280	0.349	ND						
LN	0.422*	ND							
PH	ND								

PH–plant height; LN–leaf number; RN–root number; PW–panicle weight; GW–grain weight; EPW–empty panicle weight; RDW–root dry weight; SDW–stem dry weight; LDW–leaf dry weight; ND–no data; the sample population (*n*) = 30; Values followed by (*) indicate a significant difference at $t_{0.05}$; Values followed by (**) indicate a significant difference at $t_{0.05}$.

1 Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1) and Tulungagung 2 (SG-TLG 2) (Maftuchah et al 2021). Therefore, further research and trials are needed to assess the proper cultivation method for optimizing the yield of Bioguma 1 and 2 sorghum varieties and to prepare well-performed mother plants for ratoon cropping in the next season.

Conclusions and Recommendations

In conclusion, growth characteristics of Bioguma 1, including plant height, leaf number, root number, and panicle weight, were significantly greater compared with Bioguma 2, resulting in a comparatively higher yield. However, the estimated yield of both varieties remained significantly lower than the potential yield. The grain weight of both varieties also correlated with the stem and leaf dry weight, showing the translocation of accumulated carbohydrates in stems and leaves. Based on its disease resistance, growth, and yield, Bioguma 1 could be used as the mother plant for a ratoon system. By using the ratoon system in the next season, sorghum plants could be harvested twice a year.

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