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Production competitiveness of regional sorghum genotypes against new, enhanced varieties and their morphological traits in Gunung Kidul, Yogyakarta, Indonesia

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Abstract. *Muazam A, Daryono BS, Kristamtini. 2023. Production competitiveness of regional sorghum genotypes against new, enhanced varieties and their morphological traits in Gunung Kidul, Yogyakarta, Indonesia. Biodiversitas 24: 4943-4948.* Sorghum is an important cereal crop after rice, maize, wheat and barley. Sorghum can be a potential local food to support national food security and to anticipate the threat of a world food crisis. One effort that can be made is to optimize the land by using adaptive sorghum varieties planted during the rainy season. Various new superior varieties have been released through the Ministry of Agriculture, but the germplasm with a potential to be local food has not been utilized optimally. Several studies on sorghum have been carried out from both cultivation and post-harvest aspects, but to continue the research relay and to participate in meeting regional food needs, characterization of local varieties needs to be carried out as a first step in plant breeding activities. This study aims to determine the performance of six genotypes of new high-yielding sorghum varieties and local varieties grown during the rainy season in Karangmojo Village, Karangmojo Sub-district, Gunung Kidul District, Yogyakarta Province, from October 2022 to March 2023. The design used was a Randomized Block Complete Design, with 5 repetitions. The results showed the significantly different effect of genotypes on the parameters of plant height, panicle length, panicle width, 1000 seed weight, flowering age, stem diameter, harvesting age, panicle weight per plot, and production per hectare.

Keywords: Genotyping, local varieties, production, rainy season, sorghum

INTRODUCTION

Whole grains of cereals are essential to human health because they supply a lot of energy, minerals, and dietary fiber. Regular consumption of whole grains lowers the risk of heart disease and diabetes by 20%-30% according to numerous prospective studies, enhances the control of blood sugar, improves long-term weight management, and reduces the incidence of certain types of cancer (Zeng et al. 2019; Turner et al. 2016; Xiong et al. 2019; Wang et al. 2021). One of the Poaceae family's tropical species, Sorghum [*Sorghum bicolor* (L.) Moench] is a dominant plant in Africa, Asia, and Latin America and one of the tropical species in the Poaceae family (Desmae et al. 2016). More than 35% of sorghum is grown specifically for human use. Every year, sorghum breeders create several upgraded varieties suitable to semi-arid and tropical climates (Mohamed et al. 2022). Sweet sorghum is a high-yield crop with strong resistance, which can potentially support the development of the forage farming industry (Li et al. 2023) Zekeya et al. 2014; Gajanan et al. 2016; Bouajila et al. 2022).

Sorghum has long been cultivated by Indonesian farmers either in monoculture, intercropping, or inter-cropping. Sorghum production amounts to around 4,000-6,000 tons per year and is spread across five provinces, namely West Java, Central Java, East Java, and the Special Region of Yogyakarta. Sorghum production in Indonesia is still low and scarce in the market (Karimuna et al. 2020). The low development of production and harvested area is partly due to the sorghum planting area which is still limited to dry climate areas or areas with a short rainy season. (Ibrahim 2015).

Plant growth and development are influenced by genetic and environmental factors. One of the influential environmental factors is rainfall. Rainfall is one of the climate elements with the highest fluctuation and quite significant effect on crop production (Wang et al. 2020). Rainfall that is suitable for growing sorghum is 600-1500 mm/year (Hussein et al. 2021).

A variety of sorghum growing environments includes temperatures and tropics, high and low altitudes, rainy and post-rain seasons. Rainy and post-rainy seasons affect the harvest age and flowering phase of sorghum (Msongaleli et al. 2017).

In the tropics, extreme weather associated with global climate teleconnections can have an outsized impact on food security. Sensitivity, in this context, can depend on the sub-seasonal distribution of rainfall (Ozdogan et al. 2019). . In an effort to increase sorghum production nationally, it is necessary to develop sorghum plants by expanding the planting area (Naoura et al. 2019). One of the efforts that can be made is to use varieties that are adapted to the rainy season.

Gunung Kidul has 53,962.34 dryland area out of 109,382.64 ha or 49.33% of the dryland area in Yogyakarta. Dryland generally has low soil fertility and low organic matter levels. This condition is further exacerbated by the limited use of organic fertilizers, especially in seasonal food crops (Mulima et al. 2018).

Development of sorghum has received less attention from the government, so it has been found rarely in farmers' fields. But in the last 5 years, it has begun to attract the government's attention, and now the government has made sorghum an alternative food besides rice and corn. CNBC Indonesia (2022) reported that the government, through the President, reiterated its directive on increasing production and downstream sorghum as an alternative food at NTT's sorghum harvest event. It is too risky to rely on rice commodities only to ensure national food security.

Sorghum is a cereal crop that has a high degree of adaptability to drought when compared to other cereal crops. This plant can grow in almost all types of soil. Hence, sorghum is a crop potential to be developed in Gunung Kidul as an alternative crop to meet food, feed, and industrial needs (Wang et al. 2018). What does drought-resistant sorghum look like when planted in the rainy season where rainfall is classified as high (>300mm) and very high (>500mm). So, we carry out sorghum research in the rainy season because local food (Xie et al. 2022), feed, and energy sources will expectedly be able to support national food security better.

MATERIALS AND METHODS

Study area

The study was conducted from October 2022 to March 2023 in Karangmojo Village, Karangmojo Subdistrict, Gunung Kidul District, Yogyakarta Province, Indonesia (-7.964745, 1[illegible]0.696[illegible]166). The experimental land is located at 249 m asl with a rainfall distribution of about 1750-2130 mm per year and an average temperature of 24°C.

Procedures

The procedure of research activities involved land processing and preparation by forming 30 plots with 5x6 m^2 dimension respectively, then beds with 1x6 m dimension were made on each plot until a total of 120 beds were obtained; initial fertilization (manure); planting (spacing 75 x 25 cm^2); plant maintenance; fertilization; irrigation; soil piling around the plant (*pembubunan*); pest and disease control; harvest; and post-harvest (drying). Each plot has 4 mounds; each mound has 40 planting holes, so the seeds planted in each hole are 1 seed; a total of 160 seeds or seedlings are needed in a 30 m square plot. Planting in the field with a transplanting system, seeds are sown in polybags at the age of 21 days, transplanting is carried out, and harvesting is carried out after physiologically ripe seeds. The harvest age for each variety is different.

The tools used in this study were a meter, yam stick (*tugal*), ruler, analytical scales, permanent marker, RHS (color chart), vernier, sprayer, raffia rope, label paper, digital camera, hoe, and stationery. The materials used were six sorghum genotypes, yam stick consisting of three local varieties, and three comparison genotypes: the new superior varieties Bioguma 3, Samurai, and Kawali. Other materials used were urea fertilizer, KCl, SP36, manure, pesticides, and water.

Data analysis

This study used a randomized block design (RCBD) consisting of six treatments and five replication Genotype treatments consisted of S1 (Bioguma 3 varieties purchased from BBBiogen); S3 (Plonco local variety obtained from local farmers of Gunung Kidul Yogyakarta); S4 (Samurai variety derived from BATAN); S6 (Kawali variety derived from introduction from India developed from BALITSEREALIA, Maros, South Sulawesi); V3 (Red Glutinous Sorghum local variety obtained from local farmers of Gunung Kidul, Yogyakarta); and V4 (Black Sorghum local variety obtained from local farmers of Gunung Kidul, Yogyakarta). All types of sorghum genotypes in the world are usually grown in drylands, as the historical origin of sorghum comes from the African region (Yang and Zhong 2022).

The data obtained were analyzed using analysis of variance (F test at 5% level). If the F statistic value of the treatment showed a significant difference, it was further tested using the Duncan test at the 5% level.

RESULTS AND DISCUSSION

Geographical, climate, and weather conditions of Gunung Kidul

Gunung Kidul is one of the regencies in the Special Region of Yogyakarta Province. The topography of the research locality in Karangmojo Sub-district is at 150-200 m altitude. Soil types are predominantly red Mediterranean and a combination of black concrete and limestone parent materials. Thus, even though the dry season is long, water particles are still able to survive. There is a river on the ground, but it is dry in the dry season. The depth of groundwater ranges between 60 m and 120 m below the ground level. The limitations of agricultural land and the future population growth will cause the decrease in the land's carrying capacity, so transformation and reorientation of the economic base from traditional agriculture to agricultural entrepreneurs, small industries, and trade are needed. Gunung Kidul has a tropical climate with a relatively high annual average rainfall of 300-650 mm from October to December 2022 Wijaya, (2023). Rainfall in January was recorded at 160 mm (3 days of rain for 15 days) (Table 1), and drought occurred in July, August, and September.

Sorghum can be cultivated easily with relatively low costs and can be planted monoculture or intercropped. Sorghum is also more resistant to pest and disease attacks, so the risk of failure is relatively small. In Gunung Kidul, there are 3 local varieties of sorghum that look very different from each other: Wareng black sorghum, red glutinous sorghum, and Plonco, while the comparators are Bioguma, Samurai, and Kawali. These three landraces have not been registered as Gunung Kidul's landraces. Besides the color of husk, it is also distinguished by the tips of hairs on the seeds (Figure 1).

Morphological characteristics and growth performance of different sorghum genotypes

Bioguma and Kawali are 2 m tall, taller than other species (Table 2). Despite their height, the sorghum plants would not collapse but would grow upright until harvest time. The heights of the three landrace sorghum varieties were relatively low. Bioguma has the largest diameter of the stem (2.3 cm), while the red glutinous sorghum local variety has the smallest diameter (1.2 cm). Fixed length of panicles also varied; the longest panicles were found in Red Glutinous Sorghum (*Ketan Merah*) (32 cm), the shortest ones were found in Kawali (17 cm) (Table 3).

The results show that genotype has a significant effect on the parameters of plant height; flowering period; age at harvest; stem diameter; panicle length; panicle diameter; panicle weight per plant; seed weight per plant; panicle weight per plot; yield per hectare. It can be seen from Table 2 indicating that S6 genotype has the highest value in the plant height parameter.

The widest panicles were in variety V4 (Black Wareng) with an average width of 10.64cm, including drooping panicles of the non-compact type, while the panicles of other genotypes were compact and tightly clustered. Regarding the weight of the largest panicle in the local variety Plonco (S3), which is able to compete with new superior varieties such as Bioguma (S1), Samurai (S4), and Kawali (S6), However, the weight of panicles per plot (S6) (Kawali) has the largest weight of 2727.80 grams. This was due to the fact that some plots did not have complete plants because of the high rainfall, and some died due to submergence (Table 3).

In Table 4, we can see that Kawali (S6), the national superior variety, has the largest seed weight per plant, and 1000 seed weight, along with Bioguma (S1), has a fairly high yield ability when compared to local varieties that are able to compete only with the local variety Plonco (S3). Yield quality and supporting components of production were the lowest and most linear in the local varieties of red glutinous rice (V3) and black Wareng (V4).

Table 1. Monthly rainfall average (mm) for the sorghum growing season (October to March) in Gunung Kidul, Yogyakarta Province in 2022 and 2023

Month	Precipitation (mm^3) 2022/2023	Rainy days
October	343.5	[illegible]
November	657.7	2[illegible]
December	31[illegible]	[illegible]
January	[illegible]67.[illegible]	15
February	213.0	14
March	[illegible]19.0	22
Total	[illegible]21.7	106

Figure 1. Three local sorghum varieties of Gunung Kidul. S3: fixed Plonco, V4: fixed Black Wareng, V3: fixed Red Glutinous Sorghum (*Ketan Merah*); and three national superior sorghum varieties: S1: fixed Bioguma, S4: fixed Samurai, S6: Kawali

Table 2. Average plant height, stem diameter, flowering age, and harvest age in some genotypes tested

Genotypes	Plant height (cm)	Stem diameter (mm)	Flowering age (DAP)	Harvest age (DAP)
S1	205.36 ab	23.23 a	60.40 cd	106.60 abc
S3	152.46 c	21.46 a	68.60 bc	104.00 bcd
S4	102.12 d	21.15 a	75.20 b	111.40 ab
S6	233.04 a	19.45 a	53.00 d	93.20 cd
V3	177.20 bc	12.29 b	55.40 d	90.80 d
V4	110.80 d	19.48 a	89.00 a	120.60 a
F statistic	19.35	9.09	23.50	10.92

Notes: Numbers accompanied by the same letter in the same column indicate the results are not significantly different in the 5% Duncan test. Local sorghum varieties of Gunung Kidul: S3: Plonco, V4: Black Sorghum Wareng, V3: Red Glutinous Sorghum (*Ketan Merah*); and 3 national superior sorghum varieties: S1: Bioguma, S4: Samurai, S6: Kawali

Table 3. Average panicle length, panicle diameter, panicle weight per plant, and panicle weight per plot in some tested genotypes

Genotypes	Panicle length (cm)	Panicle width (cm)	Panicle weight per plant (g)	Panicle weight per plot (g)
S1	17.56 c	6.98 b	144.72 a	2557.20 a
S3	23.31 bc	6.06 b	158.14 a	2472.60 a
S4	20.73 c	6.70 b	101.42 b	1767.61ab
S6	17.71 c	9.86 a	154.66 a	2727.80 a
V3	32.16 a	6.75 b	28.48 c	314.60 b
V4	27.04 ab	10.64 a	74.40 b	730.40 b
F statistic	9.51	7.90	22.69	7.10

Notes: Numbers accompanied by the same letter in the same column indicate the results are not significantly different in the 5% Duncan test. Local sorghum varieties of Gunung Kidul: S3: Plonco, V4: Black Sorghum Wareng, V3: Red Glutinous Sorghum (*Ketan Merah*); and 3 national superior sorghum varieties: S1: Bioguma, S4: Samurai, S6: Kawali

Table 4. Average seed weight per plant, production per hectare, and 1000 seed weight in some genotypes tested

Genotypes	Seed weight per plant (g)	Production perhectare (ton)	1000seed weight (g)
S1	58.78 ab	7.70 a	40.20 a
S3	85.96 c	8.41 a	39.00 a
S4	67.42 abc	5.38 b	20.20 b
S6	136.86 d	8.21 a	40.90 a
V3	70.81 abc	3.91 b	23.00 b
V4	57.29 a	4.00 b	23.70 b
F statistic	21.69	8.90	105.39

Notes: Numbers accompanied by the same letter in the same column indicate the results are not significantly different in the 5% Duncan test. Local sorghum varieties of Gunung Kidul: S3: Plonco, V4: Black Sorghum Wareng, V3: Red Glutinous Sorghum (*Ketan Merah*); and 3 national superior sorghum varieties: S1: Bioguma, S4: Samurai, S6: Kawali

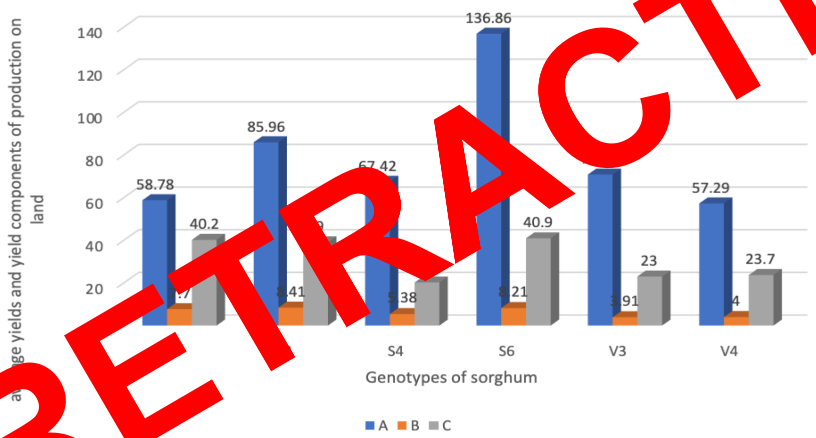

Figure 2. 3 local sorghum varieties of Gunung Kidul: S3: fixed Plonco, V4: fixed Black Wareng, V3: Red Glutinous Sorghum (*Ketan Merah*); and 3 national superior sorghum varieties: S1: fixed Bioguma, S4: fixed Samurai, S6: Kawali. A: seed weight per plant in (g), B: production per hectare (ton), C: 1000 seed weight (g)

Discussion

The different plant height indicates different genetic makeup of each genotype planted. (Pramanda et al. 2015) state that different genotypes determine different plant height. Furthermore, according to (Phuke et al. 2017), plant height is strongly affected by genetic factors. Plant growth will be optimal if the nutrients needed are available in appropriate amount and form. Nutrients N, P, and K are available in the soil in sufficient quantities so that the vegetative growth of plant's leaves, stems, and roots, will be better.

The parameter of stem diameter (Table 2) shows that V3 is significantly different from all genotypes. The stem diameter of sorghum plants can be an indicator of stem strength, making plants sturdier. Missihoun et al. (2015) state that plants with a larger stem base diameter tend to be sturdier and more resistant to damping. The development of stem diameter depends on the availability of nutrients in the soil. Nutrients can encourage the vegetative growth of plants, according to Selvia et al. (2014), including the formation of chlorophyll in the leaves that spurs the rate of photosynthesis. The observation of flowering age showed that the plants flowered between 53.00 and 89.00 days after planting (DAP).

Genotype S6 shows a low flowering age. This fact indicates the presence of environmental factors that affect the slow flowering age. The flowering period of plants, according to (Eniola et al. 2019; Gebrie 2019), is greatly affected by environmental factors, especially light intensity, rainfall, and daily temperature.

Plant's response to solar radiation is divided into three aspects: intensity, quality, and photoperiodicity. High rainfall during the research process, especially in the rainy season, can result in a different quality of solar radiation compared to the dry season. Rainfall can affect the photoperiod of plants, which has an impact on the process of photosynthesis as well as phytochrome and plant biology. Furthermore, (Alfieri et al. 2019) explained that plant growth is influenced by the photoperiod through the formation of flowers, fruits, and seeds. Aspects of plant development, including flower bloom, according to Thomas (2017), are influenced by duration of research, especially the response to the duration of light and darkness, although each variety has different sensitivity to photoperiod (Kumar et al. 2013).

The study, it was found that the harvest age ranged between 90.80 and 120.60 DAP, which is relatively normal, with sorghum harvest age usually ranging between 110 and 120 days after planting (DAP). Genotype V3 shows younger harvesting age. This shows that environmental factors affect the harvesting age of sorghum. Muui et al. (2013) state that some limiting factors in sorghum cultivation are drainage, slope, and rainfall. The differences in flowering and harvesting age under the same conditions and environment, according to (Ozdogan et al. 2019), come from the individual's genes.

The panicle is where the sorghum seeds are located. In the center of the panicle, there is a panicle axis to which the panicle branches are attached. Seeds are located on the panicle branches. Table 3 shows that genotype V[illegible] has the highest panicle length and is significantly different from all other genotypes observed. The longer the panicle, the more panicle branches, and the number of seeds that will increase seed production, according to Meng et al. 2016). (Eniola et al. 2019) stated that panicle length will determine the number of seeds per panicle. Sorghum panicles are divided into several types: solid, semi-solid, and open. Panicle width can be determined by the number of seeds contained in panicle branches. The limit of panicle width (Table 2) shows that genotype V4 is significantly different from all genotypes but S6.

The longer the panicle, the more panicle branches and the number of seeds, the higher the seed production volume, according to Meng et al. (2016). The parameter of panicle weight per plant in Table 2 shows that genotype V3 is significantly different from all tested genotypes. The number of seeds contained in the primary branches of panicles and panicle characteristics will affect the weight of panicles per plant. Kanbar et al. (2019) revealed that panicles will get heavier as the number of seeds increases. The sorghum flowers will later become sorghum grains. Panicle length, panicle diameter and greater weight of the panicle, according to (Abbasi et al. 2022), can result in the greater weight of panicle seeds. Meanwhile, the panicle weight parameters for each plot showed that S6 has the highest value and Wade termination was significantly different from all genotypes observed. Dahlberg et al. (2018) stated that the difference in genetic makeup is one of the factors causing diversity in the appearance of a plant.

Observations of seed weight per plant showed that genotype S6 had the highest value and was significantly different from all genotypes observed. Seed weight per plant (Figure 2) as an indicator of seed quality is very important to measure the yield power of a genotype. Gueye et al. (2016) found that weighty seeds are quality seeds and worthy of development. Table 4 shows that S3 has the highest potential production per hectare (8.41 tons). Each genotype has a different potential depending on its genes, according to Ghimire et al. (2021). This means that the success of a plant in producing higher production is caused by the genes of the plant itself, and therefore. The production results achieved depend on their genetic potential. In addition to genetic factors, the differences in yield power are determined by the genotype's responses to environmental conditions, nutrient absorption, and plant growth phases.

In the 1000 seed weight parameter, the results were not significantly different between S1, S3, and S6, or between S4, V3, and V4. So, it can be said that the weight of 1000 seeds variable in the genotypes observed is not uniform, ranging between 23.00 and 40.90 g. Bhusal et al. (2017) said that seed yield is determined by the number and size of seeds. This fact means that the seed sizes of all genotypes tested are relatively different. The weight of 1000 seeds is a characteristic with low variation, according to Ghimire et al. (2021). In this study, the results obtained from genotypes are not different; in fact, they have almost the same seed color and size. Furthermore, according to Ghimire et al. (2021), the 1000-seed weight is not affected significantly by the environment because seed size is controlled better by genetic factors (Figure 2).

In conclusion, the results show that the S3 genotype, as a landrace, could compete with the new and excellent varieties, and had the best growth response and yield ability in rainy season planting.

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