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Evaluation of Ratoon Potential and Yield of Some Sorghum Varieties (*Sorghum bicolor* L)

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Abstract: Sorghum production needs to be increased to meet food or feed needs because sorghum grain has nutritional qualities that are comparable to other grains such as corn. One of the advantages of the sorghum plant is the growth of new shoots from the base of the harvested stem which produces new plants, ratoon, that grow until they can be harvested. This experiment examines the ratoon potential of 5 sorghum varieties, Bioguma, Samurai, Pahat, Suri4, and the local Gando Keta variety so that we can utilize ratoon technology on these sorghum varieties. The experiment was carried out in a greenhouse using a Completely Randomized Design. It can be confirmed from this experiment that the dry matter weight of the main plants is higher compared to the ratoon plants' dry matter weight, however, the yield of the ratoon was higher than that of the main plants. Seed size contributes to the higher yield of the ratoon plants. Among all the varieties tested, Suri4 and Pahat show the best ratoon potential. Gando Keta, the local variety, has the lowest grain yield of main and ratoon compared to the other varieties.

Keywords: Ratoon; Sorghum; Varieties

Introduction

The main food requirement relies on rice, so efforts to diversify food ingredients must continue to be carried out. The increase in national rice production mainly depends on wetland rice, while the area of rice fields is decreasing due to land conversion, including non-agricultural land. Indonesia will experience difficulties in meeting its domestic rice needs. Therefore, the Indonesian government carried out the intensification and extensification of cereal crops as part of Sustainable Development Goals (SDGs) (Jaya et al., 2024) to increase the productivity of carbohydrate-producing plants as an alternative food source other than rice, including on dry land.

Sorghum (*Sorghum bicolor* L) is a cereal crop that can be developed as feed, food, and bioethanol. Parts of the sorghum plant such as seeds, stalks, leaves, stems and roots can be used. In Indonesia, sorghum is the third cereal food crop after rice and corn (Nurmala, 2003).

Sorghum is expected to be an alternative carbohydrate-producing crop because of its very wide adaptability, it can be planted when water availability is limited, including on dry land in the dry season. Sorghum is more tolerant to water shortages than corn and has the opportunity to be developed on land that is usually not planted during the dry season (Tabri et al., 2013).

Apart from being a food-crop source of carbohydrates, because of its high nutritional content (Dicko et al., 2006). Sorghum can be used as quality forage material for livestock through bioprocessing (Sirappa, 2003) and as fermented sugar (Tew et al., 2008) with quality approaching sugar cane sap for bioethanol production (Hawari et al., 2021). Ethanol from sorghum has high combustion power so it is very good as a biofuel raw material.

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Considering the many benefits of the sorghum plant, efforts need to be made to increase its production. Efforts that can be made to develop sorghum production include using a ratoon system (Azizah et al., 2022; Tsuchihashi et al., 2008). Ratooning is the practice of cultivating two or more harvests in one growing season by producing a second crop from the base of the main plant, which can provide resource use efficiency and higher economic profits compared to directly planted crops (Zhou et al., 2022) or single planting can harvest two or three times. Ratooning is one way to increase yields per unit area of land and per unit of time and can increase farmers' income, including on dry land (Paesal et al., 2021; Syuryawati et al., 2021). Sorghum is the type of food crop that has the most potential to be developed using the ratoon system. Sorghum cultivation using the ratoon system has been carried out in India, Hawaii, Australia, the Philippines, Indonesia, the United States, and Africa (Efendi et al., 2013; Enserink, 1995). Ratoon plants do not require seeds, simply use shoot regeneration, and are a useful means of starting cultivation in limited soil moisture (20-40%).

Sorghum varieties have different agricultural potential (Ardiyanti et al., 2019). The potential yield of ratoon plants varies and could be higher or slightly lower than the main crop (Livingston et al., 1914), even ratoons have a faster flowering time and a higher dry matter weight (Al-Taweel et al., 2020) and a higher 1000-grain weight (Pramono et al., 2019). It is not yet known for certain the ratoon potential of the various sorghum varieties known in NTB. Therefore, it is necessary to carry out experiments to determine the potential for ratoon in various sorghum varieties which are expected to contribute to food supply in NTB province.

Method

Experimental Design

This research was carried out using experimental methods in test pots in a greenhouse in Mataram, carried out in the period July to October 2023.

The experiment was carried out using a Completely Randomized Design using 5 sorghum varieties as treatment targets. The varieties used are Bioguma, Samurai, Pahat, Suri4, and Gando Keta sorghum varieties (a local NTB variety). As a comparison of growth and yield, sorghum seeds are also planted at the same time as the ratoon begins. Thus, there are 10 treatment variations, 5 ratoon treatments, and 5 main plant treatments (plants from seeds). Each experiment was repeated 4 times. Therefore, in this experiment, 40 treatment units will be obtained.

Experimental Implementation

Healthy and undamaged seeds, brightly colored, free from pests and diseases are selected for planting. Seed planting was carried out in experimental pots, measuring 30 cm in diameter and 30 cm deep with a volume of 12 liters. Pot (planter bag) filled with 12 kg of soil. Planter bags are placed in an open space with full sunlight in the Glass House of the Faculty of Agriculture Mataram University. The planter bag is previously irrigated until saturated 24 hours before planting, then drained. Seed planting is done twice, namely, the first planting is for plants that will be ratooned, while the second planting is for main sorghum plants (plants from seeds) that are not ratooned.

In each experimental pot, 2-3 sorghum seeds from the 5 varieties were planted, after the seeds grew, thinning was carried out at the age of 7-10 days by allowing 1 plant per experimental pot. During thinning, replanting is also carried out if empty pots or no seeds are growing. Ratooning was done after the first main plant reached the flowering phase (Growth Stage 5, around 50 days after germination) (Vanderlip et al., 1972).

Simultaneously with the planting, sorghum seeds of the same varieties were also planted (second planting) in separate pots, then maintained and observed like the ratoon plants, as a comparison.

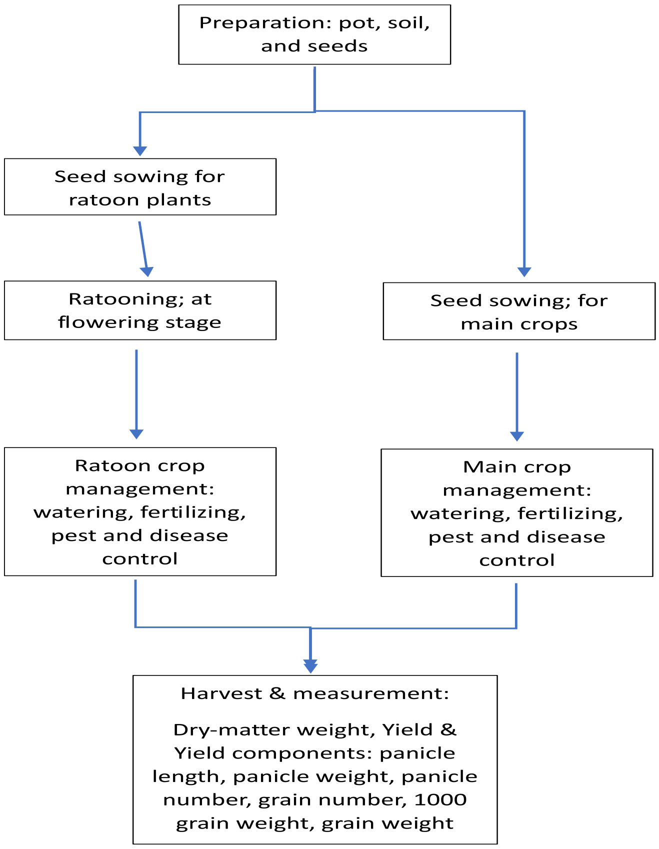

Figure 1. The steps of the experiment

Fertilization of sorghum plants is carried out at the beginning of planting at a dose of 300 kg/ha using NPK (Ponska) fertilizer (3,6 g/pot), while urea with a dose of 200 kg/ha is given in 2 applications (1,2 g each, at planting and 6 weeks old). Watering is done at intervals of 3 -4 days or if the plant is dry then water immediately. Weeding is done manually, 14 days after planting, and subsequent weeding is done as needed.

Sorghum plants are harvested when the plants reach physiological maturity. The time to harvest can be determined based on the visual characteristics of the seeds. Harvesting was carried out on plants from seeds and ratoon plants (Growth Stage 9; ± 95 days after germination) (Vanderlip et al., 1972). The steps of the experiment can be seen in Figure 1.

Observation

Each plant in each pot was then observed, both main plants and ratoon plants. Observations on plant growth were made on: the number of shoots formed on ratoon plants, plant height, number of leaves, flowering time (days), harvest time, and the dry matter weight (DM wt.). Observations were also made on the yield and yield components; sorghum seed weight, panicle length, panicle weight, and thousand grain weight (TGW).

Data Analysis

Data were analyzed using analysis of variance (ANOVA) at a level of 5%, with the Genstat Statistical Application, then continued with the least Significant Difference (LSD) test at a real level of 5%, if there is a real difference in ANOVA.

Result and Discussion

Pre-trial planting of sorghum, to prepare the sorghum plants for ratooning, was carried out on May 21, 2023, while the ratooning treatment and planting of seeds for treatment was carried out on July 23, 2023. The average air temperature from July to October 2023 was around 25ºC at night and the high temperature during the day is around 34ºC. Rainfall did not occur during the experiment, July–October is the driest month in Mataram. This affects low relative humidity (RH), around 67%. The main plants were flowering on September 3rd while the ratoon plant flowered about 10 days before. The main plant was harvested around October 4th and the ratoon on October 7th.

Plant Growth

The height of ratoon plants is higher at the start of growth compared to main plants or plants from seeds. This is because ratoon plants are grown from plant parts that have already grown, in contrast to main plants which require the growth of seedlings first. However, at the end of plant growth, the height of the main plants is higher than that of ratoon plants. The height growth of ratoon plants stops when they enter the generative phase, which is earlier than for main plants. Meanwhile, main plants still carry out vegetative growth, including plant height, because the transition to the generative phase of seed plants is slower than ratoon plants (Figure 2). The trend of growth of each variety is similar, for example in the Suri4 variety, the height growth of the Suri4 ratoon plant is faster at the beginning of growth but the Suri4 from seed is taller than the ratoon plant (Figure 3). Earlier work by Gerik, Rosethal, & Seavey, (1990) also found that the vegetative growth of ratoon plants from emergence to flowering was faster than the main plants.

In contrast to the trend of plant height, there is not much difference between the average number of leaves of ratoon plants compared to main plants (Figure 4), which can also be seen in individual varieties showing a similar trend (Figure 5, for Suri4 Variety). Differences in leaf number are more evident in different varieties.

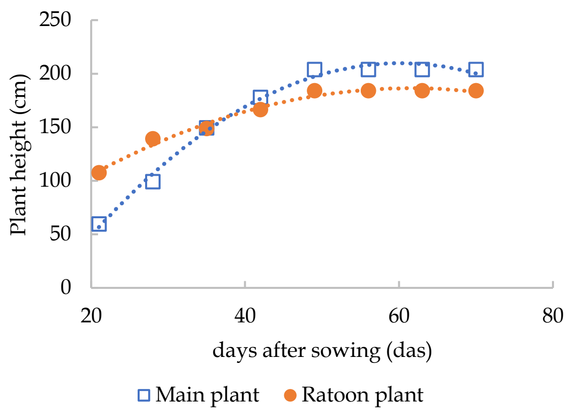

Figure 2. Comparison of the average height of ratoon sorghum plants and the height of main plants

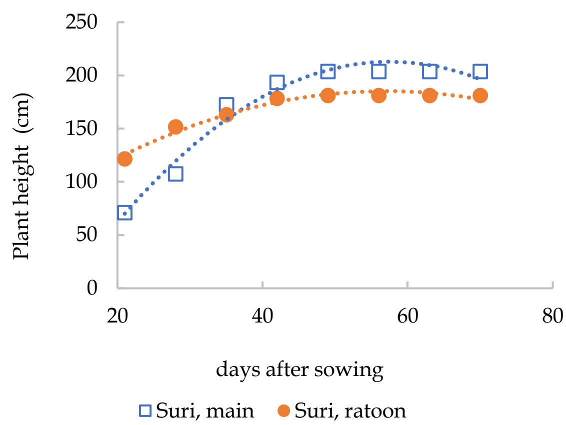

Figure 3. Comparison of the height of ratoon sorghum plants and the height of main sorghum plants in the Suri4 variety

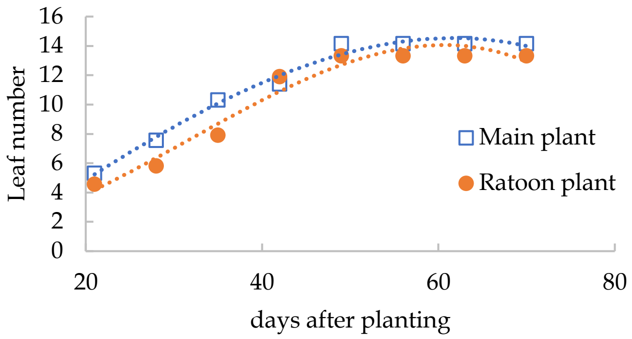

Figure 4. Comparison of the average number of leaves of ratoon plants and main plants

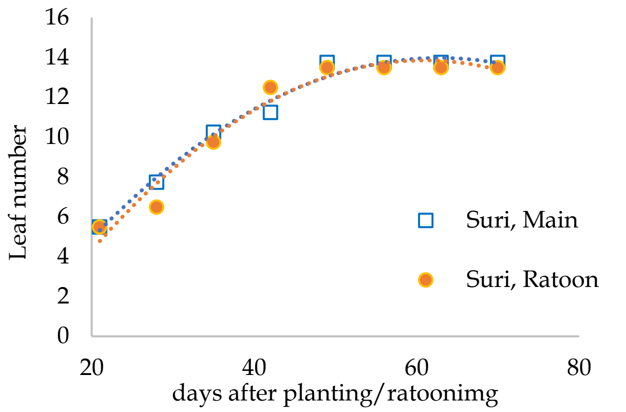

Figure 5. Comparison of the number of leaves of the Suri variety, main plants, and ratoon

The average stem diameter of the main and ratoon plants was not significantly different. Differences occur between sorghum varieties, Pahat is recorded as having the largest stem diameter,that is 18.09 mm, while Samurai has the smallest stem diameter, 14.54 mm, which is different from Pahat. The other varieties, Suri 4, Gando Keta, and Bioguma, are between the two varieties mentioned first (Table 1).

Yield and Yield Components

The growth resume for seed sorghum, when viewed from the dry matter weight (DM wt.), shows higher growth than that of ratoon sorghum. However, ratoon sorghum gave higher grain yields than main sorghum plants (Table 1).

The yield of ratoon is higher than the grain yield of the main plant, although some components yield of the main plant is higher, but this does not cause the yield of the main plants to be higher. The dry matter weight and panicle weight of the main plants were significantly heavier than the dry matter weight and panicle weight of ratoon plants. Main plants (plants from seeds) also have panicles that are longer than the panicles of ratoon plants. However, ratoon plants have a greater number of panicles than main plants, because in some experimental units, the growth of ratoons was more than one ratoon, some even reached 3 ratoons per treatment. Main plant growth was greater than ratoon plants (main plant DM wt. was 227.6 g compared to ratoon DM wt. was 162.6 g) while main plant grain yield was lower than ratoon yield (48.5 g vs 62.1 g) indicating seed yield was more affected by high temperatures compared to plant growth (Zubaidi et al., 2022).

In general, the potential yield of ratoon crops is slightly lower or the same as main crops with a faster harvest time and lower production costs, making it profitable (Al-Taweel et al., 2020; Ardiyanti et al., 2019; Pramono et al., 2019) however, ratoon can produce higher if managed well (Rogé et al., 2016). In this experiment, ratoon has the potential to provide higher yields than the main plant.

The main plants, despite having higher yield components such as head length and seed number, did not produce heavier grain yields than the ratoon plants (48.4 g vs. 62.1 g). The main factor causing this appears to be grain size; It can be seen from the thousand grain weight that the TGW ratoon is significantly higher than the TGW of the main plant (31.78 g vs. 20.08 g) (Table 1). The smaller grain size of the main plants can be caused by very high ambient temperatures, during the experiment, the temperature at the experimental location (Mataram) was around 34°C with a relative humidity of 67%. Main plants which have a longer growing season, 2 weeks longer than ratoon plants, were exposed to high temperatures for longer periods than ratoon plants. The faster growth characteristics of ratoon plants can avoid exposure to extreme conditions and can provide higher yields. Prolonged high temperatures can reduce plant growth and yield (Hatfield et al., 2015). Environmental conditions (particularly air and soil temperatures) and genetic capability governed the performance of cultivars in the ratoon cropping system (Duncan et al., 1984). Heat stress reduces pollen viability, pollen germination, grain number, and size by affecting grain setting, assimilate translocation and duration, and growth rate of grains of wheat (Akter et al., 2017) and sorghum (Djanaguiraman et al., 2014).

All varieties show a higher dry matter weight in the main plant than in the ratoon, except Samurai. Bioguma has the highest dry matter in the main plant, followed by Suri4 and Pahat, while in ratoon dry matter, Bioguma has the highest, followed by Pahat and Samurai (Table 2). For grain weight, Suri4 was the highest main plant grain weight, followed by Pahat and Bioguma, but for the ratoon plants, Pahat and Suri4 grain yield were the highest, followed by Bioguma. In this experiment, the ratoon grain yield for all varieties was higher than the main plants' grain yield, while the dry matter main plants were higher than the dry matter weight of ratoon. This confirms that grain yield is more affected by unfavorable environmental conditions than dry matter weight (Akter et al., 2017; Zubaidi et al., 2021).

Table 1. Yield and Yield Components of Main Sorghum and Ratoon Sorghum in a Glass House Experiment

	Stem diameter (mm)	Dry matter weight (g)	Panicle weight (g)	Panicle length (cm)	Panicle number	Seed number	Grain weight	Thousand-grain weight (g)
Planting system:								
Main plant	16.83	227.6	116	22.02	1.0	2410	48.4	20.08
Ratoon plants	15.99	162.6	103	16.15	2.2	1954	62.1	31.78
l.s.d.	1.997	22.9	18.5	2.57	0.17	333	9.96	2.78
Varieties:								
Bioguma	15.35	326	159	11.87	1.6	2155	55.2	25.61
Pahat	18.09	165	128	25.67	1.6	2839	68.7	24.20
Samurai	14.54	152	86	21.92	1.6	1865	39.7	21.29
Suri 4	17.69	197	122	22.22	1.6	2494	69.8	27.99
Gando Keta	16.38	136	54	13.74	1.5	1398	42.7	30.55
l.s.d.	3.157	36.2	29.3	4.06	0.266	526	15.2	4.40

Table 2. Interaction between Planting Systems and Varieties on Dry Matter Weight and Grain Weight

	DM wt.			Grain wt.		
	Ratoon	Main	%diff.	Ratoon	Main	%diff.
Varieties:						
Bioguma	311	342	-9.1	62.3	48.8	29.2
Pahat	116	214	-45.8	81.5	55,8	49.2
Samurai	171	133	28.6	41.1	38.0	7.9
Suri 4	105	288	-63.5	72.8	66.7	9.1
Gando Keta	110	161	-31.6	52.5	32.9	59.6
lsd.		51.2			22.7	

Ratoon has a higher grain weight because the 1000 grain weight is higher even though the number of seeds is less. The higher grain weight in ratoons is probably due to the longer seed-filling process compared to main crops because ratoon plants enter the generative phase (flowering age) earlier (around 10 days earlier) while the harvest time is almost the same. Longer grain filling duration can increase yield (Gambín et al., 2011; Ostmeyer et al., 2020).

The varieties Suri4 and Pahat gave the highest yields in this experiment (69.8 g and 68.7 g), then Bioguma had lower yields (55.2 g), and Gando Keta and Samurai gave the lowest yields (42.7 g and 39.7 g) (Table 1). This also shows that Pahat and Suri4 have a greater ratoon potential than other varieties (81.5 g and 72.8 g respectively; Table 2).

Conclusion

The dry matter weight of the main plants is higher compared to the ratoon plants' dry matter weight; however, the yield of ratoon was higher than that of the main plants. Seed size contributes to the higher yield of the ratoon plants. Among all the varieties tested, Suri4 and Pahat show the best ratoon potential. Gando Keta, the local variety, has the lowest grain yield of main and ratoon compared to the other varieties.

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Author Contributions

This is the contribution of the individual author: A. Zubaidi is responsible for coordinating and carrying out all research activities, conceptualization, writing—original draft preparation; D. R. Anugrahwati: experimental design, writing—review and editing; B. E. Listiana: experimental methodology, data analysis; N. H. Nufus: investigation, data collection; A. P. Azhari: formal data analysis, data validation.

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Conflicts of Interest

The authors declare no conflict of interest." And "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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