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Research Article

Agronomic Characteristics and Forage Yield of Brown Midrib (BMR) Sorghum in The Ratoon System

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ABSTRACT

Brown Midrib (BMR) sorghum is a mutation-derived variety with low lignin and high non-structural carbohydrate content, potential as a ruminant forage. The ratoon system allows for repeated harvesting without replanting, thus providing an efficient forage supply. This study aimed to evaluate the agronomic characteristics and biomass productivity of BMR mutant sorghum in primary plants, the first and second ratoon. The study was conducted experimentally using a randomized block design with three treatments (primary, first ratoon, and second ratoon plants) and four replications. The parameters observed included agronomic components (plant height, number of tillers, stem diameter, and leaf size), stem sugar value (Brix), proportion of plant structures (stems, leaves, and panicles), panicle production, forage production, and livestock carrying capacity. The results showed that plant height was not significantly different ($P>0.05$) between primary and ratoon plants, while stem diameter and leaf size decreased gradually from the first to the second ratoon. The Brix value showed a highly significant difference ($P<0.01$), with the highest value in the first ratoon and the lowest in the second ratoon. The proportion of stems and leaves decreased in the second ratoon, whereas the proportion of panicles and panicle production increased significantly ($P<0.01$). The highest forage production was obtained in the second ratoon at 52.08 tons/ha, while the total production of the three harvests reached 112.28 tons/ha with a carrying capacity of 8.8 AU/ha. From the results of this study, it can be concluded that the ratoon system does not reduce the biomass productivity of BMR mutant sorghum and can maintain agronomic quality until the second ratoon. With its high production potential and good regrowth ability, BMR mutant sorghum is worthy of development as a sustainable forage source in ruminant livestock farming systems.

Keywords: agronomic characteristics, brix, brown midrib sorghum, carrying capacity, ratoon

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) can regrow (ratoon) after the first harvest, allowing for repeated harvests without replanting. The ratoon system does not require seeds; it only maintains the remaining harvest stems for shoot regeneration (Mahpuzah et al., 2025). This system is highly advantageous for farmers because it reduces production costs and increases land use efficiency. The Numbu variety is a national variety known for its ability to grow in ratoons (Sriagtula and Sowmen, 2023; Mahpuzah et al., 2025). However, not all sorghum lines or varieties are suitable for the ratoon system, which is characterized by significantly higher yields than ratoon crops.

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In the ratoon system, agronomic characteristics of the plant can change because of the utilization of energy reserves from the stems and roots after the first harvest. These changes include stem growth, leaf size, stem sugar content, and biomass distribution among stems, leaves, and panicles. Brown Midrib (BMR) sorghum is a sorghum strain/variety developed through mutation techniques with gamma irradiation. BMR sorghum has a lignin content of only 3%–4% (Sriagtula et al., 2022), much lower than conventional sorghum, which has a lignin content of 6–77%. The low lignin content in BMR sorghum is linear with its high total non-structural carbohydrate (CNT) content, thereby improving the digestibility and quality of ruminant feed (Sriagtula et al., 2017; Sriagtula et al., 2021). Furthermore, CNT content is a source of energy that influences regrowth (ratoon) after harvest (Budiman et al., 2011).

The evaluation of agronomic components from the primary crop to the ratoon crop in BMR sorghum is important for determining growth performance and production potential as forage in ruminant farming. Ratoon crops with high sugar content (Brix) have the potential to be cultivated using the ratoon system (Lestari et al., 2022). Previous research on the potential of the first ratoon has been conducted by Zhou et al. (2022), Lestari et al. (2022), and Sriagtula and Sowmen (2023), and on the potential of the sorghum ratoon to the second ratoon (Mahpuzah et al., 2025) on non-BMR sorghum plants. Information on the ratoon potential of BMR mutant sorghum lines is still limited, which have higher sugar content than non-BMR sorghum (Sriagtula et al., 2017), indicating excellent forage quality and high energy value for ruminant farming. This study examined the biomass productivity of the BMR mutant sorghum line in primary plants, first ratoons, and second ratoons, and calculated the carrying capacity in ruminant livestock farming.

MATERIAL AND METHODS

Research Location and Design

The experiment was conducted in the Edufarm of the Faculty of Animal Science, Universitas Andalas, Padang, West Sumatra, Indonesia. The research location was at -0.910354, 100.465370, and the rainfall during the research period ranged from 120 to 863 mm/month (Figure 1), which was categorized as low to very high. The research land is ultisol soil with pH 5.5, organic matter 3.15%, total N 0.32%, available P 1.86 ppm, and total K 0.372%. The seeds used were the BMR mutant sorghum line Patir 3.7 from the Silviculture Laboratory, SEAMEO-BIOTROP, Bogor. The fertilizers used were urea, TSP, and KCl at rates of 100 kg/ha, 76.7 kg/ha, and 100 kg/ha, respectively (Sriagtula et al., 2019). A randomized block design was used, with three treatments and four replications. The treatments comprised primary plants, first ratoon plants, and second ratoon plants. There were four experimental plots, each measuring 4 m × 5 m, with a planting distance of 20 cm × 60 cm; therefore, the total number of plants per plot was 166.

BMR Sorghum Cultivation

BMR sorghum seeds were planted 5 cm deep with 2–3 seeds per planting hole. After germination, thinning was conducted to leave one well-grown plant per planting hole. Fertilizers were applied twice, at 14 and 40 days after sowing. Half the urea dose was applied during the first fertilization, and the remaining dose during the second fertilization. TSP and KCl were applied in their entirety during the first fertilization. Harvesting of the primary crop was conducted when 50% of the plants in the plot had reached the soft dough stage, approximately 95 days after sowing. Harvesting was performed by cutting the stems 5–10 cm above the soil surface. The remaining stems (stumps) of the primary plants grew new shoots, known as the first ratoon plants. Fertilization of the first ratoon plants was conducted seven days after sowing (DAS), or the day

after harvesting the primary plant, at the same dose as the primary plant. Ratoon plants were not thinned to determine germination and production. The first ratoon crop was harvested after 50% of the plants had entered the soft dough phase, approximately 80 days after planting. The remaining stems of the first ratoon plant were maintained until they sprouted again, known as the second ratoon plants. The maintenance of the second ratoon plant was the same as that of the first ratoon plant. The second ratoon plant was harvested at the soft dough phase 80 days after planting. The carrying capacity was determined based on the total forage production data harvested from the primary plant, first ratoon, and second ratoon (tons/ha) divided by the livestock's need for fresh forage. It is assumed that livestock consume 35 kg of fresh forage/day/AU (Indonesian conditions) or 10% of their body weight

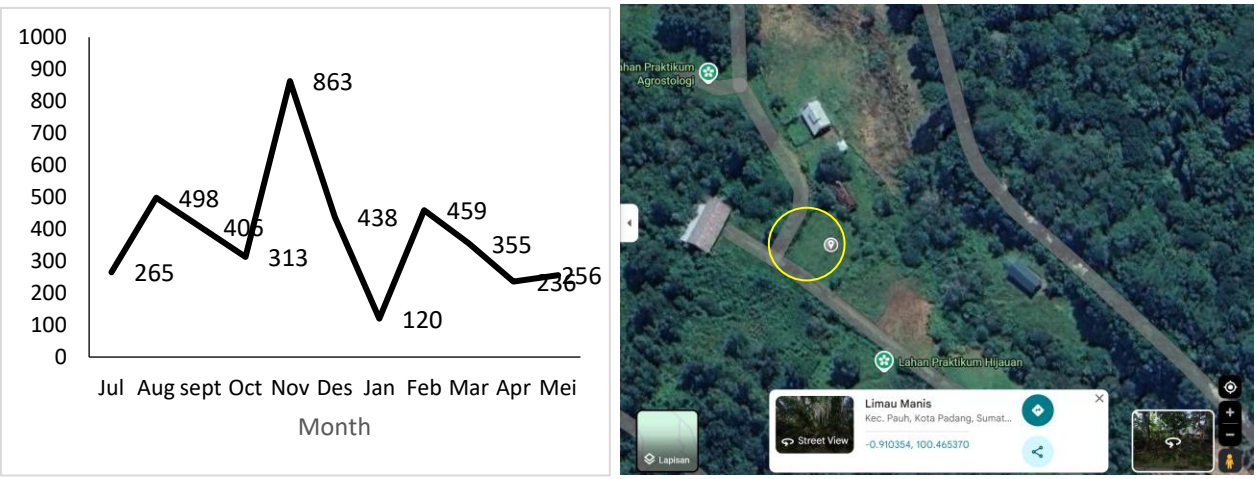


Figure 1. Rainfall (mm). Source: https://psda.sumbarprov.go.id (left) and image of research location. Source: https://www.google.com/maps/place/Edufarm+Faterna+Universitas+Andalas (right)

Parameters Measured

The observed parameters included the number of tillers, plant height, stem diameter, number of leaves, leaf length and width, stem sugar value (Brix), proportion of stems, leaves, and panicles, panicle production, fresh fruit production, and carrying capacity. Parameter measurements were conducted on ten randomly selected plants in each plot (Sriagtula et al., 2017).

Data Analysis

The data obtained were subjected to analysis of variance using the randomized block design in the SPSS 20 software. If significant differences were found, Duncan's multiple range test (DMRT) was performed.

RESULTS AND DISCUSSION

Sorghum Agronomic Profile and Brix Value

Plant height, stem diameter, and Brix value of BMR mutant sorghum are presented in Figure 2. The height of BMR mutant sorghum plants did not show a significant difference (P>0.05) between primary and ratoon plants 1 and 2, with values of 181.72 cm, 179.58 cm, and 180.58 cm, respectively. The insignificant difference in ratoon plant height with primary plants in this study is relevant to the findings (Harahap et al., 2023) of 238.65 cm, 252.85 cm, and 247.75 cm in Samurai I sorghum, respectively. Although the age of sorghum ratoon plants when reaching the

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soft dough phase was shorter (80 DAR) than that of primary plants (95 DAS), it did not cause a significant decrease in plant height in ratoon plants one and two. This research contradicts the findings (Saputro & Harsono, 2023) that ratoon plants have lower plant heights than primary plants.

This study found that ratoon plants with two stems had the smallest diameters compared to ratoon plants with one stem and primary plants, at 10.79 mm, 13.5 mm, and 17.04 mm, respectively. This aligns with the findings of Saputro and Harsono (2023), who reported that ratoon plant stem diameters are smaller than those of primary plants. These results contradict the findings of Zubaidi et al. (2024), Zhou et al. (2022), and Kuswoyo et al. (2025), who reported that ratoon plant diameters do not differ from those of primary plants. The decrease in stem diameter in this study is due to the shorter growth period of ratoon plants and their tendency to mature more quickly, thus limiting secondary growth and stem thickening. These characteristics are suitable for maximizing yields within a limited timeframe. In addition, the low stem diameter in the second ratoon was caused by the number of shoots growing in the second ratoon being more than in the first ratoon, with 4.63 and 2.33 shoots, respectively (Figure 4). In accordance with the statement by Gomathi et al. (2013), ratoon plants experienced a decrease in shoot production of 17.0% to 28.1%.

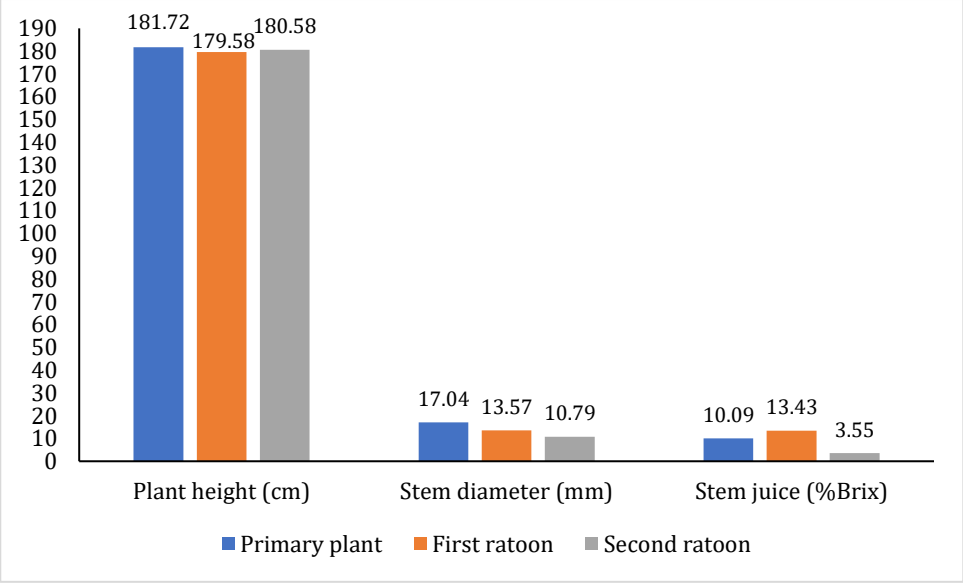


Figure 2. Agronomic profile and Brix value of sorghum in primary and ratoon plants

The Brix value of the stem juice of the BMR mutant sorghum showed a highly significant difference ($P<0.01$) between the primary and ratoon plants. The sugar content in Ratoon 2 was lower than that in Ratoon 1 and the primary plants, with values of 3.55, 13.43, and 10.09% Brix, respectively. The lower Brix value in Ratoon 2 can be explained by the higher panicle percentage in Ratoon 2 compared to Ratoon 1 and the primary plants, at 18.63%, 18.72%, and 18.63%, respectively (Table 1). Sorghum plants have two sinks, namely, the stem and the panicle, whose priority is influenced by their growth phase. When sorghum plants enter the generative phase, the panicle becomes the main sink for carbohydrate accumulation for forming seeds, compared to sucrose accumulation in the stem. During the grain filling phase, sorghum plants adjust their metabolism, which affects the concentration of soluble sugars in the stem juice, which is directly correlated with the Brix value. According to Sriagtula et al. (2025), the proportion of panicles affects the quality of stem juice. Sorghum stems store non-structural carbohydrates, especially

sucrose, which is crucial in determining the Brix value (Sriagtula et al., 2017; Bihmidine et al., 2015). The low Brix value in Ratoon 2 indicates low ratoon ability, in accordance with the statement by Lestari et al. (2022) that sorghum with a high Brix content has the potential for regrowth. A high Brix value reflects a high CNT content, which is an energy source that can affect ratoon power (Budiman et al., 2011). This is evidenced by the very low shoot regrowth after the Ratoon 2 harvest, so that sorghum plants are only effectively cultivated with the ratoon system until Ratoon 2 (third harvest).

The results of the study showed a significant difference ($P<0.01$) in leaf length and width but not in leaf number ($P>0.05$) (Figure 3). Leaf size (leaf length and width) in primary plants continued to decrease from the first to the second ratoon. Smaller leaf size is a physiological adaptation of ratoon plants that grow faster, with a priority on stem and panicle growth.

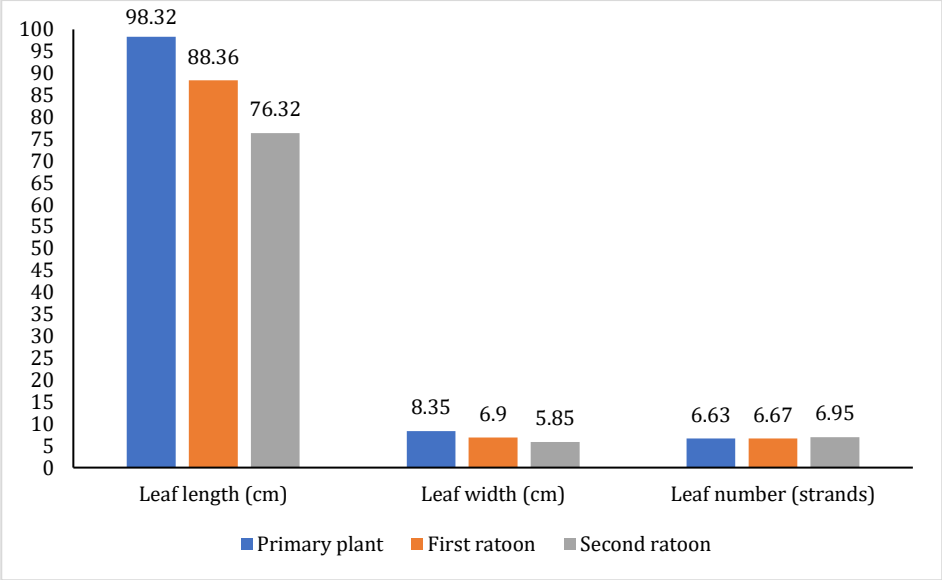


Figure 3. Morphology of sorghum leaf in the primary and ratoon plants

Figure 4 shows that Ratoon 2 produced more tillers than Ratoon 1. This is supported by the higher Brix value of the stem in ratoon 1 compared to the primary plant, respectively 13.43% and 10.09%. (Figure 2). The Brix value represents the energy content that affects the ability of shoot regrowth; the higher the Brix value, the higher the ratoon ability (Budiman et al. 2011; Lestari et al. 2022). The results of this study contradict the findings (Harahap 2023) that the number of tillers in Ratoon 1 and 2 ranged from 1 to two tillers.

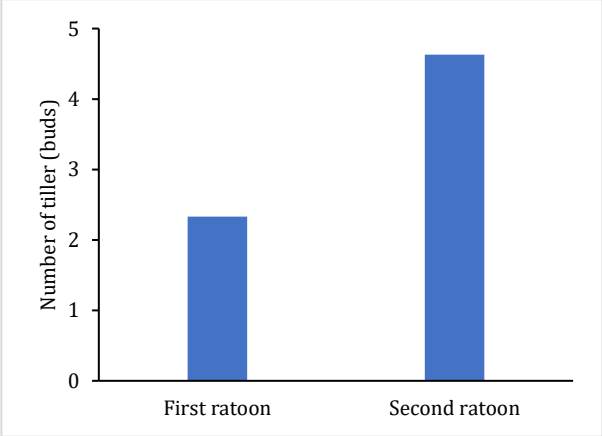


Figure 4. Number of tillers (buds)

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Proportion of Stem, Leaf, Panicle, and Panicle Production

The results of the variance analysis (Table 1) showed that the percentage of stems, leaves, and panicles differed significantly (P<0.01) between primary and ratoon plants. Ratoon 2 plants had the lowest percentage of stems compared to primary plants and ratoon 1, while the percentage of stems between primary plants and ratoon 1 showed no significant difference (P>0.05). This is in line with the trend of increasing panicle percentage with ratoon 2, with the lowest percentage of stems, producing the highest percentage of panicles. These results contradict the findings of Harahap et al. (2023), because increasing harvesting time until ratoon 2 resulted in a rising proportion of fresh stems (%) but a decrease in the proportion of panicles and fresh leaves (%).

Table 1. Stem, leaf, panicle proportion, and panicle production (fresh basis)

Parameters	Primary crop (95 DAS)	First ratoon (80 DAR)	Second ratoon (80 DAR)
% Stem	56.57±3.05^{ab}	58.78±2.27^{a}	55.00±9.80^{b}
% Leaf	24.80±3.32^{A}	22.50±1.83^{B}	14.19±4.64^{C}
% Panicle	18.63±1.85^{B}	18.72±2.34^{B}	22.13±4.47^{A}
Panicle production (ton/ha)	6.66±1.38^{B}	4.55±1.12^{C}	12.04±4.66^{A}

Panicle production had a significant effect (P<0.01) on primary plants and ratoons; the highest panicle production was measured in ratoon 2 at 12.04 t ha-1. The higher panicle production in ratoon 2 was due to the higher percentage of panicles in ratoon 2. The soft dough phase in sorghum is the phase of grain filling and accumulation of non-structural carbohydrates, especially in the form of starch, which can affect panicle weight (Sriagtula et al., 2016). A higher percentage of linear panicles is associated with increased panicle production.

Forage production and potential carrying capacity

Sorghum forage production (whole plant) is presented in Table 2. The results of the analysis of variance showed that forage production had a very significant effect (P<0.01) on primary plants and ratoons. The highest biomass production was found in ratoon 2, reaching 52.08 t ha-1. This was due to the high number of tillers and the proportion of panicles in ratoon 2. The results of this study are relevant to the findings of Harahap et al. (2023), who reported that ratoon 2 produced the highest biomass compared to primary plants and ratoon 1.

Table 2. Biomass production and carrying capacity

Fresh production (ton/ha)			Cumulative production (ton/ha)	Carrying capacity (AU/ha)
Primer plant (95 DAS)	First ratoon (80 DAR)	Second ratoon (80 DAR)		
35.77±3.71^{B}	24.43±4.11^{C}	52.08±5.90^{A}	112.28	8.8

As shown in Table 2, during the second defoliation, the total forage production (primary plants, ratoon 1, and ratoon 2) could meet the livestock's fresh forage needs of approximately 8.8 AU/ha. The potential carrying capacity of sorghum forage (whole plant) was higher than that of Taiwan grass and pakchong until the third defoliation, at 7.40 AU/ha and 7.75 AU/ha, respectively (Ernawati et al., 2023).

CONCLUSION

The ratoon system for cultivating BMR mutant sorghum does not reduce the biomass productivity of BMR mutant sorghum and maintains agronomic quality until the second ratoon. Owing to its high production potential and good regrowth ability, BMR mutant sorghum is worthy of development as a sustainable forage source in ruminant livestock farming systems.

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