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Nutrient quality of hybrid sorghum with different planting densities on beach ridges interspersed with swales (BRIS) soil in Bachok, Kelantan

Thayalini, K.[1*], Nasyah Rita Azira, M. N.[1], Thiyagu, D.[2], Muhammad Najib, O. G.[3] and Mohd Rosly, S.[1]

[1]*Livestock Science Research Centre, MARDI Headquarters, 43400 Serdang, Selangor, Malaysia*
[2]*Industrial Crops Research Centre, MARDI Bachok, Kampung Aur, Mukim Jalan Kandis, 16310 Bachok, Kelantan, Malaysia*
[3]*Industrial Crops Research Centre, MARDI Headquarters, 43400 Serdang, Selangor, Malaysia*

Abstract

The livestock industry in Malaysia is a growing industry and to sustain the nutritional requirement of the population, there is a need to rely on imported meat and milk due to insufficient supply. To further grow the livestock industry, it is crucial that sufficient forage crop can be grown locally to meet animal feed requirements in a more sustainable way. Increasing use of agriculture land by including nutrient deficient soils such as beach ridges interspersed with swales (BRIS) soil for forage growth can enhance local feed production, thus reducing the need for more cost-intensive imported feed. In this study, three varieties of forage hybrid sorghum, namely megasweet (MS), brown midrib (BMR) and sugar graze (SG), grown in the nutrient deficient BRIS soil with different planting densities were analysed. The yield for MS was the highest for the first harvest, however, the nutrient contents were not significantly different among the three hybrids. Likewise, for the second harvest, the total yield was not significantly different between MS, BMR and SG. Nutrient quality was also not affected by the planting density between crops, showing suitability of all three forage hybrid sorghum varieties to be grown in BRIS soil to supplement livestock nutritional requirements.

Keywords: hybrid sorghum, BRIS soil, planting density, nutrient quality

Introduction

The soil area in Malaysia is approximately 33 million ha, wherein about 40% are located in West Malaysia and about 60% located in East Malaysia (DOA 2020). However, there are large portions of the soil which are believed to be unsuitable for agriculture and are categorised as nutrient deficient soils.

Among the nutrient deficient soils in Malaysia include BRIS soil, which are sandy deposits occurring mainly along the east coast area of Peninsular Malaysia (Idris 2015). These soils have very poor physical and chemical properties due to the lack of clay in the soil. BRIS soils can be considered as sandy soils as almost 90% of the soil consists of sand (Hj Toriman et al. 2009). In Malaysia, despite BRIS soil's reputation as a nutrient deficient soil, however, agricultural related studies in such land are increasing to further improve crop production (Mohd Yusoff et al. 2017). Among the unfavourable characteristics of BRIS soil are its high sand content, hard layered and unstructured texture, low pH content between 3.4 to 5.8, as well as low water and nutrition retention capacity. Moreover, this type of soil has very loose and large particles. It is dry and very porous, thus inhibiting organic matter build-up, leading to losses from leaching of applied fertilisers. This type of soil does not absorb water like other soils due to its very large particle size. The poor moisture retaining characteristic of BRIS soils typically results in high soil temperatures which retards growth of crop (Anem 2011).

Livestock industry is among the industry that relies heavily on crop for feedstock. The livestock industry in Malaysia is crucial for the country's agricultural development. It provides a wide range of employment opportunities to the locals, providing meat, milk and dairy products to Malaysians. Among the challenges faced by the livestock industry are the dependence on imported feed and the rising cost of feed. One way to overcome this problem is to reduce feed imports and increase

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Authors' full names: Thayalini Kathiraser, Nasyah Rita Azira Mohd Abdul Nasir, Thiyagu Devarajan, Muhammad Najib Othman Ghani and Mohd Rosly Shaari
Corresponding author: drlini@mardi.gov.my

local feed production. By optimising the use of nutrient deficient soils such as BRIS soil which have limited use in agriculture (as discussed above), the production of local forage resources can potentially be increased.

Sorghum [*Sorghum bicolor* (L.) Moench] is a plant native to Africa and belongs to the grass family, *Graminea*. Forage sorghum is particularly suitable as ruminant feed due to its high nutrient qualities such as high dry matter content, high protein, as well as low lignin. Forage sorghum will usually be harvested 45 – 50 days after planting before flowering. Physically, sorghum is capable of reaching heights of up to 3.8 m. The stems can grow as thick as 1.5 cm and the leaves are very large, up to 4 cm wide and can grow up to 1 m long (Cameron 2006). The root is a type of fiber. Due to its unique morphological and physiological characteristics, forage sorghum was introduced as a drought resistant crop and as such, has less water requirements than other crops such as corn. Corn yields are lower in hot tropical conditions such as in Malaysia which imports more than 3.5 million tonnes of grain corn annually, with more than 60% used for animal feed (Nazmi et al. 2022).

The production of quality forage crops is very important for ruminants. Forage sorghum is unique in that it is able to regrow even when harvested repeatedly, and has valuable features such as drought resistance and ability to grow in high temperatures or dry conditions. The hardy characteristics of forage sorghum shows potential for cultivation in nutrition deficient BRIS soil. Furthermore, it can be cut fresh and made into straw or silage to be given to livestock. Therefore, to maximise soil usage in Malaysia for livestock feed, the objective of this study was to evaluate three hybrid sorghum varieties with three different planting densities in BRIS soil.

Materials and methods

Experimental design

The study was conducted at MARDI Bachok, Kelantan. For this study, factorial design was used. Three varieties of forage sorghum, namely megasweet (MS), brown midrib (BMR) and sugar graze (SG) hybrids were planted in BRIS soil with three planting densities of 75 x 9.3 cm, 75 x 10.3 cm, and 75 x 11.3 cm, using a mechanisation system (*Figure 1*). Based on the layout plan for the experimental plots, the total layout area is 41 m x 41 m. Each replicate consists of five rows (*Figure 2*). The results were harvested over two cycles, over a total period of 95 days, at intervals of 50 and 95 days (*Figure 3*). Sorghum samples that had been cut 10 – 15 cm from ground level, were randomly used with three replicates for each

Figure 1. Sorghum planting in BRIS soil MARDI Bachok, Kelantan

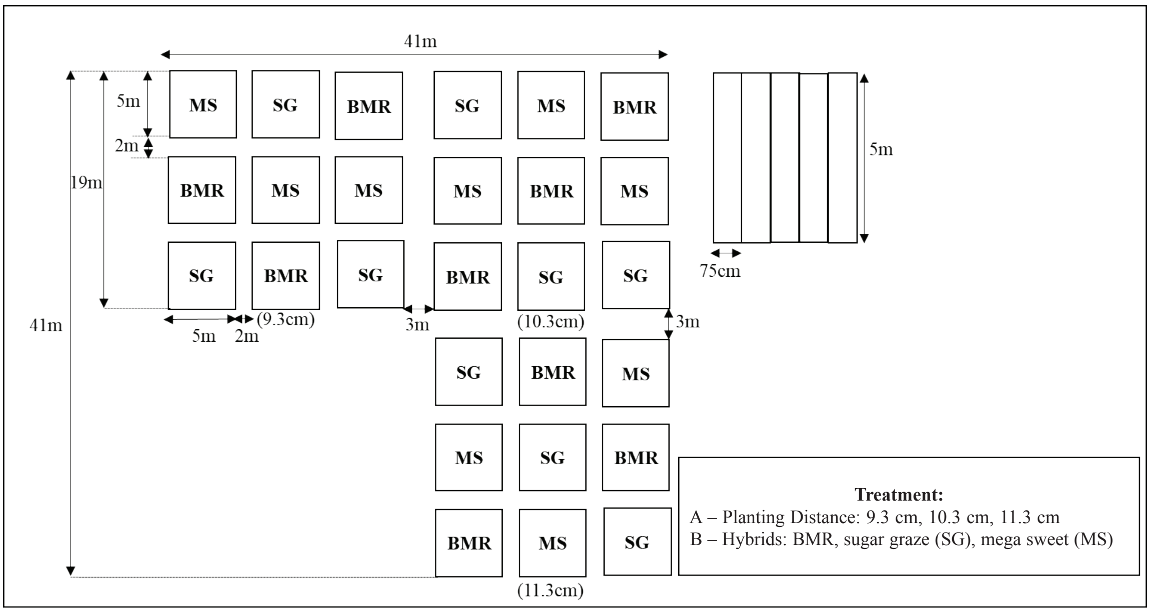

Figure 2. Sorghum experimental plot layout, MARDI Bachok, Kelantan

Figure 3: Sorghum during harvest

hybrid. Next, it was chopped and dried at 60 °C in an oven for three days or more until it reached a constant weight before being ground for proximate analysis. The total yield from each harvest cycle was also recorded. The total yield was calculated as total average/ha basis derived from each experimental plot.

Proximate analysis of the sorghum samples was performed based on standard methods describeds in AOAC (2010). The sorghum samples were analysed for dry matter (DM), ash, organic matter (OM), crude protein (CP), crude fat (CF), lignin, neutral detergent fibre (NDF) and acid detergent fibre (ADF). DM content was calculated based on difference between fresh sample and oven-dried sample and the samples were then subjected to combustion in a furnace for subsequent ash and OM determination. Kjeldahl method was used for the estimation of CP, whereas ether extract analysis was used to determine CF. Detergent solution was used to remove digestible material and soluble fibre for NDF and ADF determination.

Statistical analysis

The data obtained were analysed statistically using Analysis of Variance (ANOVA) method and Duncan's Multiple Range Test using SAS 9.3 software to test the level of significance ($P < 0.05$).

Results and discussion

Forage sorghum parameters

In this study, all three varieties of hybrid sorghum were grown at three different planting densities as described above. This study was conducted using different planting densities to observe if there would be any differences in the proximate analysis and yield. The total yield is shown in *Table 1* and *Figure 4*, while the average values for nutrient composition for each parameter such as dry matter (DM), ash, organic matter (OM) crude protein (CP), crude fibre (CF), lignin, neutral detergent fiber (NDF) and acid detergent fibre (ADF) for the first and second harvest respectively are shown in *Table 2* and *Table 3*.

Forage sorghum harvest yield

Referring to *Table 1* and *Figure 4*, based on the results of harvest yield, at the first harvest (after 50 days of planting), MS had 30.21% significantly higher total harvest yield compared to BMR. There was no significant difference between the total yield of MS and SG. However, after the second harvest, there was no significant difference between the three hybrids planted at the different planting densities.

Forage sorghum nutrient quality

As for nutrient composition, higher values for dry matter percentage indicate that the water content is less. The dry matter content of all hybrids during the first harvest was in a lower range (7.6 – 10.1%) compared to the second harvest (9.9 – 13.7%). For the second harvest, the average dry matter obtained for MS for all planting densities studied was in the range of 9.9 – 11.2%. As for SG, the average dry matter for the second harvest for all planting densities studied was in the range of 10.3 – 12.4%. As for BMR, for all planting densities studied, the average dry matter was in the range of 11.0 – 13.7% for the second harvest. For both harvests, overall MS had the lowest dry matter percentage, although the results were not significant among the three hybrids.

Ash is the residue remaining after all organic matters have been burnt out. It also represents the mineral content of the forage. However, nutritionally it has little importance. For the first harvest, SG and BMR had higher

Table 1. Total yield of forage sorghum in BRIS soil

Hybrid	First harvest (t/ha)	Second harvest (t/ha)
BMR	38.84^{b}	37.19^{a}
MS	50.57^{a}	36.10^{a}
SG	44.58^{ab}	34.48^{a}

ab Min values with different alphabets are significantly different at the level of $p < 0.05$

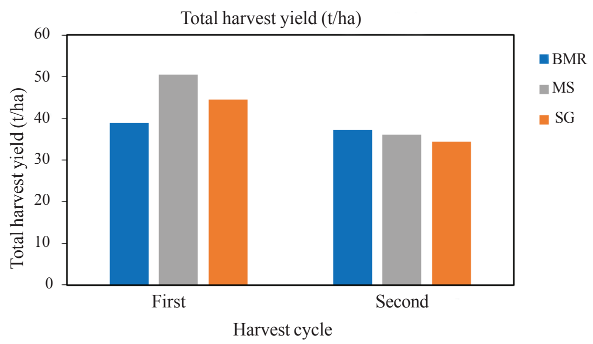

Figure 4. Total forage sorghum yield for first and second harvest cycle

Table 2: Nutrient composition for three hybrid sorghum in the first harvest

Hybrid	Planting density (cm)	First harvest yield							
		Dry matter, DM (%)	Ash (%DM)	Organic matter, OM (%DM)	Crude protein, CP (%DM)	Crude fibre, CF (%DM)	Lignin (%DM)	Neutral detergent fibre, NDF (%DM)	Acid detergent fibre ADF (%DM)
Sugar graze (SG)	75x9.3	7.6^{b}	9.1^{a}	6.9^{b}	12.1^{ab}	8.6^{a}	8.6^{a}	73.4^{ab}	59.1^{ab}
	75x10.3	8.3^{ab}	8.8^{ab}	7.6^{b}	11.8^{ab}	7.2^{a}	7.2^{a}	73.7^{ab}	53.8^{ab}
	75x11.3	7.9^{b}	8.3^{abc}	7.2^{b}	13.1^{a}	6.6^{a}	6.6^{a}	69.4^{b}	50.8^{b}
Brown midrib (BMR)	75x9.3	9.1^{ab}	7.4^{bcd}	8.4^{ab}	12.7^{ab}	7.2^{a}	7.2^{a}	77.9^{a}	57.2^{ab}
	75x10.3	8.7^{ab}	8.0^{abc}	8.0^{ab}	12.5^{ab}	9.9^{a}	9.9^{a}	75.5^{a}	54.4^{ab}
	75x11.3	9.4^{ab}	8.0^{abcd}	8.6^{ab}	12.3^{ab}	8.6^{a}	8.6^{a}	76.3^{a}	55.9^{ab}
Mega sweet (MS)	75x9.3	8.8^{ab}	7.0^{cd}	8.2^{ab}	10.2^{b}	7.7^{a}	7.7^{a}	74.2^{ab}	53.8^{a}
	75x10.3	8.7^{ab}	6.8^{cd}	8.1^{ab}	10.8^{ab}	12.0^{a}	12.0^{a}	75.4^{a}	55.3^{ab}
	75x11.3	10.1^{a}	6.5^{d}	9.5^{b}	11.1^{ab}	8.0^{a}	8.0^{a}	79.3^{a}	60.2^{ab}
P-value		0.1348	0.0067	0.0861	0.2061	0.0332	0.6914	0.0478	0.3263

[ab] Min values with different alphabets are significantly different at the level of $p < 0.05$

Table 3: Nutrient composition for three hybrid sorghum in the second harvest

Hybrid	Planting density (cm)	Second harvest yield							
		Dry matter, DM (%)	Ash (%DM)	Organic matter, OM (%DM)	Crude protein, CP (%DM)	Crude fibre, CF (%DM)	Lignin (%DM)	Neutral detergent fibre, NDF (%DM)	Acid detergent fibre, ADF (%DM)
Sugar graze (SG)	75x9.3	10.3^{bc}	6.4^{a}	9.6^{bc}	10.1^{ab}	43.8^{a}	18.8^{ab}	80.6^{ab}	60.4^{a}
	75x10.3	12.4^{ab}	5.5^{a}	11.8^{ab}	8.5^{bc}	40.4^{ab}	15.2^{bc}	81.7^{ab}	59.0^{a}
	75x11.3	10.9^{bc}	6.6^{a}	10.2^{bc}	10.7^{a}	39.2^{b}	21.7^{a}	77.7^{b}	56.0^{a}
Brown midrib (BMR)	75x9.3	11.0^{bc}	6.6^{a}	10.3^{bc}	10.7^{a}	41.8^{ab}	14.5^{bc}	80.9^{ab}	63.1^{a}
	75x10.3	13.7^{a}	5.8^{a}	12.9^{a}	8.9^{abc}	40.1^{ab}	15.1^{bc}	83.1^{a}	64.3^{a}
	75x11.3	11.7^{abc}	5.9^{a}	11.0^{abc}	10.8^{a}	39.0^{b}	14.4^{bc}	81.2^{ab}	54.6^{a}
Mega sweet (MS)	75x9.3	9.9^{c}	5.6^{a}	9.3^{c}	10.1^{ab}	39.8^{ab}	18.6^{ab}	83.4^{a}	63.0^{a}
	75x10.3	11.2^{bc}	5.4^{a}	10.6^{abc}	8.0^{c}	41.8^{ab}	10.6^{c}	81.0^{ab}	56.0^{a}
	75x11.3	11.2^{bc}	5.4^{a}	10.6^{abc}	10.2^{ab}	39.7^{ab}	22.1^{a}	80.8^{ab}	57.6^{a}
P-value		0.0412	0.3828	0.0523	0.036	0.283	0.0025	0.2606	0.2707

[ab] Min values with different alphabets are significantly different at the level of $p < 0.05$

ash content ranging from 7.4 – 9.1% compared to MS which had the lowest ash content, ranging from 6.5 – 7.0% at all planting densities. After the second harvest, the ash content decreased for all hybrids at the different planting densities and ranged between 5.4 – 6.6%. However, there was not much variation between the results of ash content from second harvest. The ash content for all hybrids at the different planting densities were within the range reported by Ahmed et al. (2019) who recorded minimum value of 5.7% and maximum value up to 12.41% of ash content for various forage sorghum grown on sandy soil.

The next parameter, which is organic matter, refers to all nutrients contained upon combustion of samples, with the exception of ash (mineral content). The organic matter content of all hybrids during the second harvest was in the higher range (9.3 – 12.9%) compared to the first harvest (6.9 – 9.5%). Based on the results obtained from the second harvest, the average organic matter obtained for BMR ranged from 10.3 – 12.9% for all the planting densities. As for SG, the average organic matter obtained for all planting densities in the second harvest was in the range of 9.6 – 11.8%, whereas for MS, the values ranged between 9.3 – 10.6%. For both harvests, however, there were no significant differences (P >0.05) between all the hybrids at different planting densities. The higher range of organic matter obtained from the second harvest is inversely related to ash content which decreased in the second harvest as discussed above. This finding correlates with the observation of Gois et al. (2019) who reported that organic matter values found in forage sorghum were inversely proportional to mineral material, wherein higher ash content relates to lower organic matter contained in the forage and vice versa.

With regards to crude protein, typically, the protein content in forage is moderate, i.e. less than 10%, and for ruminants, additives or concentrates are supplied to meet protein requirements which are typically in the range of 14 – 19%. In the first harvest, it was found that the average protein content obtained for MS, BMR and SG for all planting densities studied were in the range of 10.2 – 11.1%, 12.3 – 12.7% and 11.8 – 13.1%, respectively. For the second harvest, it was found that BMR had a higher average protein content compared to MS and SG. Yet, the average range of protein content for the second harvest is typically less than that of the first harvest. The data obtained for the average crude protein content for all hybrids are almost identical to the results of previous studies. Ahmed et al. (2019), showed that the percentage of protein content for some types of forage sorghum grown in sandy soils was on average 9.2% with a maximum value reaching 12%.

Crude fibre is important for the fermentation of food components in the stomach and intestines of ruminant livestock despite having low energy content. It consists of plant cell components including cellulose, hemicellulose, lignin and pectin. Based on crude fibre yield, in the first harvest, MS at a planting density of 9.3 cm had the highest value at 43.3%, while BMR at the same planting density had the lowest value at 33.4%. However, not much difference exists between the three hybrids. For the second harvest, the crude fibre content is between 39.0 - 43.8%. Nevertheless, the difference in fibre content was not significant (P >0.05) for all three hybrid sorghum at all the planting densities. Ahmed et al. (2019) showed that the percentage of crude fibre content for some types of forage sorghum grown in sandy soils is in the range of 32 – 45% and these results are quite similar to the results of studies that have been conducted.

Low lignin content allows food to be more easily digested by livestock due to the ruminant digestive system not having the ability to digest lignin. It was found that in the first and second harvest, all three hybrid sorghum at all cultivation planting densities contained lignin content between 6.6 – 12.0% and 10.6 – 22.1%, respectively. Compared to the MS and SG hybrids, for the second harvest, on average, BMR had the lowest lignin content. Overall, the average percentage of lignin in this study was within the range of 1.3 – 22.2% as reported by Chakravarti et al. (2017).

Neutral detergent fibre (NDF) refers to the total hemicellulose, cellulose and lignin content of the forage. NDF is negatively correlated with feed intake. In other words, NDF is a measure of feed capacity for the animal. For the first harvest, the NDF content for MS at different planting densities ranged from 74.2 – 79.3%, whereas the NDF content for BMR ranged from 75.5 – 77.9%. Both MS and BMR have higher NDF content compared to SG, whose values ranged from 69.4 – 73.7%. After the second harvest, the NDF content was in a slightly higher range for all three hybrids, however, there were no significant differences (P >0.05) for all the hybrids at different planting densities. The NDF content for SG ranged from 77.7 – 81.7%, whereas for BMR and MS, the NDF content ranged from 80.8 – 83.4%. These values are in proximity of the range of 70 – 80% for forage sorghum as reported by Chakravarti et al. (2017).

Acid detergent fibre (ADF) is a measure of plant component in forages that are least digestible in the livestock, which includes cellulose and lignin. ADF is negatively correlated with digestibility, therefore forages with high ADF concentrations are typically lower in energy. In other words, ADF is a measure of energy that can be derived from feed to be used by the animal. The ADF content is typically lower than NDF content due to absence of hemicellulose. Based on the results of the first harvest, the ADF content for all three hybrids planted at different planting densities ranged from 50.8 – 60.2%. After the second harvest, the ADF results ranged from 54.6 – 64.3% for all three hybrids at different planting densities. However, there were no significant differences (P >0.05) for all the hybrids at different planting densities for both harvest cycles. Similar to other findings, the ADF results are within the range of 47 – 79% as reported by Chakravarti et al. (2017).

There were not many significant differences between the nutrient values of all three hybrid sorghum, however, as MS has the highest yield in the first harvest, it shows greater potential to be grown in BRIS soil.

Conclusion

In conclusion, as per first harvest, MS has the highest total yield although there were no significant differences in the yield for the second harvest. The nutrient values, however, were not significantly different in the first and second harvest between all three hybrid sorghum at the different planting densities. This study suggests that nutrient deficient soil such as BRIS is suitable for production of forage sorghum especially MS variety. As this is a small-scale study, further detailed studies in a larger scale are required for more significant results.

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