

Alternative Agronomic Management Practices Through Fertilizer, Irrigation, and Plant Density Adjustments for Hybrid Fodder Sorghum (*Sorghum bicolor* L. Moench)

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ABSTRACT

Purpose: The basal fertilizer recommendation for growing hybrid fodder sorghum varieties in uplands involves relatively high quantities of Urea, TSP, and MOP, with rates of 100:90:65 kg/ha for SX-17 and 150:62:37 kg/ha for Dairy green. For both initial and ratoon crops, it is recommended to apply 150 kg/ha of urea as a top dressing. This study investigated the impact of reducing the fertilizer application rate to 75% and employing alternative agronomic practices on hybrid fodder sorghum varieties grown in lowland fallow paddy fields in the dry zone during the Yala and third seasons.

Research Method: The agronomic management practices, including four basal fertilizer rates (Urea:TSP:MOP) of 100:90:65 (BD1), 150:62:37 (BD2), 75:68:49 (BD3), and 113:47:28 (BD4); two top-dressing urea fertilizer rates of 150 (TD1) and 112.5 kg/ha (TD2); two plant spacing configurations of 45x30 (WS) and 45x15 cm (NS); and two irrigation interval regimes, 5 days up to 30 days followed by 8 days (SI) and 7 days up to 30 days followed by 10 days (LI) were investigated. These factors were combined into four agronomic management packages: AMP1 (BD1, TD1, WS, SI), AMP2 (BD2, TD1, NS, SI), AMP3 (BD3, TD2, WS, LI), and AMP4 (BD4, TD2, NS, LI). The study used a split-plot design with three replicates and assessed various parameters, including plant height, stem diameter, plant weight, leaf area index (LAI), number of tillers, and fodder yield in both the initial fodder sorghum crop and the first ratoon crop. The crops were harvested when 50% of the panicles on the plants were at the milk and dough grain stages.

Findings: The initial crop exhibited significantly heavier plants having wider stems when grown with higher fertilizer rates, wider plant spacing, and shorter irrigation intervals in AMP1. Irrespective of fertilizer rate and irrigation interval, the initial crops tended to have higher LAI with narrow plant spacing in AMP2 and AMP4. In the ratoon crops, wider plant spacing in AMP1 and AMP3 resulted in clumps with a greater number of tillers and heavier plants. However, the ratoon crops also exhibited higher LAI with narrow plant spacing in AMP2 and AMP4. Total fodder dry matter yield (DMY) in AMP2 and AMP4 with narrow plant spacing was significantly greater for both varieties. Furthermore, the DMY was not affected by fertilizer rate and irrigation interval.

Value: Hybrid fodder sorghum varieties (SX-17 and Dairygreen) cultivated at higher plant density, along with reduced fertilizer (75%) and irrigation, can produce comparable fodder yield (21.1 and 26.1 MT/ha, respectively) to those grown at lower plant density with more fertilizer and irrigation (24.6 and 28.1 MT/ha, respectively) in lowland paddy fields during Yala and third seasons in the dry zone.

Keywords: Plant height, Stem diameter, Plant weight, Number of tillers, LAI, Dry matter yield

INTRODUCTION

Domestic milk production in Sri Lanka meets only 38% of the national requirement (Central Bank of Sri Lanka, 2019), thus the country heavily depends on imported dairy products.

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Dairy cattle farmers are in need of high-quality feed to increase milk productivity. Fodder sorghum (*Sorghum bicolor* L. Moench) has become an important forage for intensive dairy cattle farming in the country. The crop is presently cultivated in uplands with supplementary irrigation. However, with greater demand for uplands for the cultivation of other field crops (OFC) the expansion of fodder sorghum in uplands is limited. A considerable extent of lowland paddy fields lie fallow during the *Yala* season (382,863 ha and 53173 ha in 2019 and 2020, respectively) in the dry zone (SEPC, 2019; 2020). Fodder sorghum could be cultivated in these lowland fallow paddy fields as an additional source of income for dry zone farmers.

The growth and yield of crops like fodder sorghum are significantly influenced by agronomic management practices (AMP), including fertilizer application rate, irrigation interval, and plant density. Studies have shown that increasing the rate of nitrogen (N) and phosphorus (P) fertilizer application enhances the yield of fodder sorghum (Mahmud *et al.*, 2003). Similarly, frequent irrigation has been found to increase the dry matter yield (DMY) of sweet sorghum (Vasilakoglou *et al.*, 2011). However, it is important to note that the absorption of essential elements such as N and P becomes difficult when the soil lacks sufficient water content to facilitate nutrient uptake by the plant roots. Insufficient nutrient absorption due to deficiencies negatively impacts plant growth and development, and ultimately reduces the yield (Jahanzard *et al.*, 2013). Therefore, proper irrigation planning is crucial to maintain a balanced water supply that meets the crop's demands. Additionally, row spacing and seed rate significantly affect the yield of fodder sorghum (Malik *et al.*, 2007). Narrow row spacing has been shown to result in higher fodder yield due to improved light interception and water use efficiency (Scott *et al.*, 1999). The seed rate also plays a significant role in influencing both green fodder yield (Mahmud *et al.*, 2003) and DMY (Uzun *et al.*, 2004) of fodder sorghum. However, it's worth noting that a study by Berenguer and Faci (2001) found that higher plant density can lead to water deficiency for individual plants, resulting in lower fodder yield in sorghum.

A few fodder sorghum varieties have gained popularity among upland dry zone farmers in Sri Lanka. Urea, TSP, and MOP in the basal fertilizer recommendation for hybrid fodder sorghum varieties grown in uplands is quite high (100:90:65 and 150:62:37 kg/ha for SX-17 and Dairygreen, respectively). Additionally, a recommended top-dressing urea application of 150 kg/ha is suggested for both the initial crop and the ratoon crop. Appropriate agronomic management

practices for cultivating fodder sorghum in lowland paddy fields are yet to be recommended. This study aimed to examine the effects of a lower fertilizer application rate (75%) combined with alternative agronomic management practices on the growth and DMY of selected hybrid fodder sorghum varieties (SX-17 and Dairygreen) cultivated in lowland fallow paddy fields in the dry zone during the *Yala* and third seasons. The experiment was approved by the Ethical Clearance Committee (ECC) of the Faculty of Agriculture, University of Peradeniya (ECC/2022/E/043).

MATERIALS AND METHODS

Experimental Site

The hybrid fodder sorghum varieties known as SX-17 and Dairygreen were cultivated at the Field Crops Research and Development Institute (FCRDI) – Mahailluppallama. The experimental site is located at 8°7'12.34" north latitude and 80°27'34.14" east longitude, with an elevation of approximately 121.19 m. This location receives an average annual rainfall of 1750 mm, and the temperature typically maintains around 27°C (Punyawardena, 2010). The predominant soil type at the experimental site is Reddish Brown Earth (RBE) (Dassanayake *et al.*, 2020).

Experimental Design and Data Collection

During the *Yala* season in 2021, the sorghum seeds were manually planted, and the crop was continued for the ratoon crop in the third season. The study examined various agronomic management practices (AMPs), including four different basal dressing fertilizer rates: 100:90:65 (BD1), 150:62:37 (BD2), 75:68:49 (BD3), and 113:47:28 (BD4) of Urea, TSP, and MOP, respectively. Additionally, two top-dressing urea fertilizer rates were assessed: 150 (TD1) and 112.5 (TD2) kg/ha. The plant spacing options were 45x30 (WS) and 45x15 (NS) cm, while the irrigation intervals for flood irrigation were either 5 days up to 30 days followed by 8 days (SI) or 7 days up to 30 days followed by 10 days (LI).

The AMPs were divided into four different agronomic management packages, namely: (i) AMP1 consisting of BD1, TD1, WS, SI; (ii) AMP2 consisting of BD2, TD1, NS, SI; (iii) AMP3 consisting of BD3, TD2, WS, LI; and (iv) AMP4 consisting of BD4, TD2, NS, LI, as shown in Table 1. The experimental site was appropriately blocked based on variations in drainage, soil fertility, etc. Each experimental plot had a size of 25 m². The experimental agronomic

management packages (AMP1, MAP2, AMP3, AMP4) were arranged as a split-plot design with three replicates. The basal-dressing fertilizer mixture was applied two days before seeding, while the top-dressing fertilizer mixtures were applied at five weeks of age for the initial crop and at one week of age for the ratoon crop. The experimental plots were manually weeded and protected from pests and diseases using recommended pesticides and fungicides throughout the duration of the experiment. Experimental fodder sorghum plots were harvested when 50% panicles of the plants reached the milk and dough grain stage. The initial crop and ratoon crop were harvested at 9 and 8 weeks of age, respectively. From each plot, three representative plants were harvested, and plant height, stem diameter, and fresh weight were measured. These plants were dried at 65°C until a constant weight was achieved and the dry matter content was computed. Fodder sorghum from a randomly selected 1 m² area in each plot was used to measure the leaf area index (LAI) and fresh matter yield. The DMY of each plot was also estimated. Rainfall data at the experimental site were recorded on a weekly basis. The performance of the hybrid fodder sorghum varieties under different agronomic management packages was assessed through analysis of variance (ANOVA), followed by mean comparison using Duncan's Multiple Range Test considering a 95% probability level for significance in the SAS statistical package (SAS Inc., 2009). When the interactions between AMPs and variety were found to be significant, the results were analyzed separately for each variety.

RESULTS AND DISCUSSION

Growth of the Initial Sorghum Crop

The application of AMP significantly influenced plant height, stem diameter, weight, and LAI ($P < 0.05$), whereas the variety only had a significant effect on plant height and LAI of the initial sorghum crop (Table 2, Table 3). The effect of AMP on the plant height of SX-17 was not statistically significant ($P > 0.05$). However, when Dairygreen was cultivated with wider spacing, higher levels of fertilizer, and increased irrigation (AMP1), taller plants were observed ($P < 0.05$) compared to those grown with narrow spacing (AMP2, AMP4). These findings are consistent with previous studies on sorghum, which have reported taller plants when grown with wider spacing (Cho *et al.*, 2004) and higher rates of nitrogen fertilizer application (Afzal *et al.*, 2012). The increase in plant height may be attributed to the higher soil nitrogen levels, resulting in an increased number of nodes and internodal length. However, Raei and Sharifi

(2009) reported taller sorghum plants with narrow plant spacing.

Both sorghum varieties exhibited significantly heavier plants with wider stems ($P < 0.05$) when cultivated with wider spacing with higher levels of fertilizer and more irrigation (AMP1) compared to those grown with narrow spacing (AMP2, AMP4). Hussein and Alva (2014) also found that the irrigation interval and the application rate of NPK fertilizer significantly affected the weight of sorghum plants. Specifically, the highest fertilizer application rate (N:P: K at 144:33.6:128 kg/ha, respectively) and optimal irrigation resulted in the highest dry weight of fodder sorghum plants (49.4 and 49.6 g/plant, respectively). These findings on stem diameter align with the results of Shahrajabian *et al.* (2020), who reported maximum and minimum stem diameters (20.56 and 15.81 mm, respectively) when sorghum was cultivated at the lowest and highest plant densities (250,000 and 400,000 plants/ha, respectively). Furthermore, despite decreasing row spacing in fodder sorghum, wider stems were observed with increasing N fertilization. It was also noted that the management package with 75% less fertilizer and low irrigation frequency (AMP3) recorded statistically similar ($P > 0.05$) plant heights and diameters in comparison to the package with relatively higher fertilizer application and high irrigation frequency (AMP1) at the same level of plant density. This trend would be much more beneficial when the crop is grown in paddy lands during the relatively drier Yala season. Although the effect of variety on stem diameter was not statistically significant ($P > 0.05$) in the present study, Ayub *et al.* (2010) demonstrated significant variations in stem diameter among different fodder sorghum varieties.

The LAI had a positive impact on the fodder yield of sorghum varieties, as observed in a study by Shahrajabian *et al.* (2011). Fodder sorghum cultivated with narrower spacing (AMP2, AMP4) exhibited a higher tendency to have a greater LAI compared to those cultivated with wider spacing (AMP1, AMP3). In a study conducted by Shahrajabian *et al.* (2020) to investigate the effects of plant density and N fertilization on LAI in fodder sorghum, it was found that sorghum cultivated at higher plant density (400,000 plants/ha) had a significantly greater LAI value of 9.22 compared to those cultivated at lower plant densities (4.25, 5.42 and 6.31 at 250,000, 300,000 and 350,000 plants/ha, respectively). Furthermore, when fodder sorghum was cultivated with a higher amount of N fertilizer (240 kg N/ha), it resulted in a higher LAI value compared to those cultivated without N fertilizer application (8.81 vs. 6.85). Another study by Pradhan *et al.* (2015)

Table 1: The agronomic management packages of the experiment

Agronomic management practices	Agronomic Management Package (AMP)			
	AMP1	AMP2	AMP3	AMP4
Fertilizer level:	F1	F2	75% F1	75% F2
-Basal-dressing (Urea:TSP: MOP kg/ha)	100:90:65 (BD1)	150:62:37 (BD2)	75:68:49 (BD3)	113:47:28 (BD4)
-Top-dressing for the first crop (Urea kg/ha)	150 (TD1)	150 (TD1)	112.5 (TD2)	112.5 (TD2)
-Top-dressing for ratoon crop (Urea kg/ha)	150 (TD1)	150 (TD1)	112.5 (TD2)	112.5 (TD2)
Plant spacing (cm x cm)	45 X 30 (WS)	45 X 15 (NS)	45 X 30 (WS)	45 X 15 (NS)
Plant density (plants/ha)	73,926 (LD)	147,852 (HD)	73,926 (LD)	147,852 (HD)
Irrigation interval:				
-Up to 30 days (days)	5 (SI)	5 (SI)	7 (LI)	7 (LI)
-After 30 days (days)	8 (SI)	8 (SI)	10 (LI)	10 (LI)
F1; Recommended fertilizer rate for SX-17, F2; Recommended fertilizer rate for Dairy green, DB; Basal dressing, TD; top-dressing, WS; Wide spacing, NS; Narrow spacing, LD; low density, HD; High density, SI; Short irrigation interval, LI; Long irrigation interval				

Table 2: Effect of agronomic management practices on plant height, stem diameter and weight of the initial crop of hybrid fodder sorghum in Yala season

Agronomic management package	Plant height (cm) ‡		Stem diameter (cm) ‡		Plant dry weight (g/plant) ‡	
	SX-17	Dairygreen	SX-17	Dairygreen	SX-17	Dairygreen
AMP1	227.2 ± 15.9 ^{aB}	310.0 ± 6.5 ^{aA}	2.2 ± 0.1 ^{aA}	2.1 ± 0.1 ^{aA}	170.6 ± 14.4 ^{aA}	163.0 ± 24.1 ^{aA}
AMP2	215.7 ± 16.3 ^{aA}	254.0 ± 18.0 ^{cA}	1.5 ± 0.1 ^{bA}	1.3 ± 0.1 ^{cA}	101.1 ± 9.8 ^{bA}	92.8 ± 14.4 ^{bA}
AMP3	221.8 ± 6.3 ^{aB}	302.3 ± 8.7 ^{abA}	1.9 ± 0.1 ^{abA}	1.8 ± 0.1 ^{abA}	139.2 ± 19.9 ^{abA}	140.8 ± 15.1 ^{abA}
AMP4	199.5 ± 13.4 ^{aB}	269.2 ± 8.1 ^{bcA}	1.5 ± 0.0 ^{bA}	1.4 ± 0.0 ^{bcA}	114.3 ± 7.5 ^{bA}	106.8 ± 13.9 ^{bA}
Significance of the effects:						
-Management		0.0004		<0.0001		0.0002
-Variety		<0.0001		0.2981		0.6678
-Management x Variety		0.0849		0.9532		0.9777
CV		15.4		21.2		30.1
‡, Mean±SE						
Within a row means followed by different capital superscript letters are significantly different (P<0.05).						
Within a column means followed by different simple superscript letters are significantly different (P<0.05).						

Table 3: Effect of agronomic management practices on leaf area index (LAI) of the initial and the ratoon crop of hybrid fodder sorghum in Yala and third seasons

Agronomic management package	Initial crop ‡						Ratoon crop ‡					
	SX-17			Dairygreen			SX-17			Dairygreen		
AMP1	3.5	±	0.2 ^{abA}	3.1	±	0.4 ^{aA}	3.5	±	0.4 ^{bA}	3.8	±	0.6 ^{bA}
AMP2	4.8	±	0.6 ^{aA}	3.9	±	0.4 ^{aA}	5.9	±	0.6 ^{aA}	6.4	±	0.4 ^{aA}
AMP3	3.1	±	0.3 ^{bA}	2.7	±	0.2 ^{aA}	3.3	±	0.3 ^{bA}	4.0	±	0.7 ^{bA}
AMP4	5.1	±	0.5 ^{aA}	3.2	±	0.2 ^{aB}	6.0	±	0.7 ^{aA}	3.9	±	0.3 ^{bA}

Significance of the effects:

-Management	0.0106	<0.0001
-Variety	0.0133	0.4391
-Management x Variety	0.3455	0.0122
CV (%)	34.1	27.1

‡, Mean±SE

Within a column means followed by different simple superscript letters are significantly different at $p < 0.05$ probability.

Within a row and a harvest means followed by different capital superscript letters are significantly different at $p < 0.05$ probability.

Table 4: Effect of agronomic management practices on plant dry weight and number of tillers of the ratoon crop of hybrid fodder sorghum in third season

Agronomic management package	Plant dry weight (g/clump) ‡						Number of tillers (tillers/clump) ‡					
	SX-17			Dairygreen			SX-17			Dairygreen		
AMP1	202.5	±	11.8 ^{aA}	234.5	±	28.4 ^{aA}	2.3	±	0.2 ^{aA}	2.6	±	0.3 ^{aA}
AMP2	160.3	±	13.0 ^{aA}	169.6	±	10.3 ^{bcA}	1.8	±	0.1 ^{bB}	2.4	±	0.1 ^{abA}
AMP3	183.6	±	22.2 ^{aA}	212.7	±	34.5 ^{abA}	2.0	±	0.0 ^{abB}	2.8	±	0.3 ^{aA}
AMP4	153.1	±	19.3 ^{aA}	126.0	±	8.8 ^{cA}	2.1	±	0.1 ^{abA}	2.0	±	0.0 ^{bA}

Significance of the effects:

-Management	0.0003	0.0228
-Variety	0.3988	0.0016
-Management x Variety	0.3084	0.0250
CV (%)	27.5	18.8

‡, Mean±SE

Within a column means followed by different simple superscript letters are significantly different at $p < 0.05$ probability.

Within a row and a harvest means followed by different capital superscript letters are significantly different at $p < 0.05$ probability.

showed a significant increase in LAI in fodder sorghum when irrigated at 20 days and again at 40 days of age (3.70) compared to irrigating only at 20 days of age (1.22), 40 days (2.34) age or not irrigate at all (2.42). However, it is worth noting that the irrigation intervals used in the present study are much shorter compared to those used in Pradhan *et al.* (2015) study.

Growth of the Ratoon Sorghum Crop

Although tillers were not observed in the initial fodder sorghum crops, they were produced in the ratoon crops. The impact of AMPs on the growth parameters of

the ratoon crop is presented in Table 3 and Table 4. The number of tillers showed a significant ($P < 0.05$) influence from both AMPs and variety. However, plant weight and LAI were significantly ($P < 0.05$) affected only by AMPs. The number of tillers and plant weight tended to be higher when sorghum was cultivated with wider plant spacing (AMP1, AMP3) compared to those cultivated with narrower plant spacing (AMP2, AMP4). Similarly, as observed in the initial sorghum crops, the LAI tended to increase with narrower plant spacing (AMP2, AMP4) compared to wider plant spacing. This could be attributed to reduced competition for nutrients, water, and light,

Table 5: Effect of agronomic management practices on dry matter yield (DMY) of the initial and the ratoon crop of hybrid fodder sorghum in Yala and third seasons

Agronomic management package	First crop yield (MT/ha) ‡		Ratoon crop yield (MT/ha) ‡		Total yield (MT/ha) ‡	
	SX-17	Dairygreen	SX-17	Dairygreen	SX-17	Dairygreen
AMP1	8.7 ± 0.7 ^{bcA}	10.2 ± 0.5 ^{bcA}	10.1 ± 0.5 ^{abA}	11.5 ± 0.3 ^{bA}	18.9 ± 0.6 ^{bcB}	21.8 ± 0.9 ^{bcA}
AMP2	11.5 ± 0.5 ^{aA}	12.0 ± 0.6 ^{abA}	12.9 ± 1.0 ^{aB}	15.9 ± 0.7 ^{aA}	24.6 ± 1.5 ^{aA}	28.1 ± 0.7 ^{aA}
AMP3	7.8 ± 0.5 ^{cA}	8.3 ± 0.3 ^{cA}	8.6 ± 0.7 ^{bbB}	11.7 ± 1.1 ^{bA}	16.5 ± 0.9 ^{cbB}	20.2 ± 0.8 ^{cA}
AMP4	10.1 ± 0.6 ^{abB}	14.9 ± 2.8 ^{aA}	10.8 ± 0.8 ^{abA}	10.8 ± 0.6 ^{bA}	21.1 ± 1.3 ^{abA}	26.1 ± 3.5 ^{abA}
Significance of the effects:						
-Management	<0.0001		<0.0001		<0.0001	
-Variety	0.0004		0.0010		<0.0001	
-Management x Variety	0.0031		0.0803		0.2774	
CV	15.7		16.7		11.6	
‡, Mean±SE						
Within a row means followed by different capital superscript letters are significantly different (P<0.05).						
Within a column means followed by different simple superscript letters are significantly different (P<0.05).						

which likely contributed to the significantly greater ($P < 0.05$) number of tillers and weight of sorghum clumps observed with wider plant spacing in sorghum.

According to Shahrajabian *et al.* (2011), the number of tillers in fodder sorghum was significantly influenced by seed rate and N fertilizer application. At a plant density of 250,000 plants/ha without N fertilizer application, the number of tillers was higher compared to that at a density of 400,000 plants/ha with an application of 250 kg/ha of N fertilizer (3.28 vs. 2.24 tillers/clump). Similarly, Manjunatha *et al.* (2014) reported a higher number of tillers in the ratoon fodder sorghum crop with wider row spacing and increased N fertilizer application. The greatest number of tillers (80.9 tillers/m) was observed with a wider row spacing of 60 cm, whereas narrow row spacing of 45 cm and 30 cm resulted in lower numbers of tillers (75.9 and 61.1 tillers/m, respectively). Furthermore, they found that the highest number of tillers (99.0 tillers/m) occurred with an N fertilizer application rate of 300 kg/ha, while rates of 240, 180, and 120 kg/ha resulted in lower numbers of tillers (81.0, 62.4, and 48.12 tillers/m, respectively).

On the other hand, when the management packages with relatively lower fertilizer rates and longer irrigation intervals are adopted (AMP3 and AMP4) no significant differences were observed ($P > 0.05$) in plant weight, number of tillers and LAI in comparison to the management packages with higher fertilizer rate and shorter irrigation interval (AMP1 and AMP2), with the exception in Diarygreen for LAI showing higher nutrient and water use efficiencies with AMP3 and AMP4.

Fodder Yield of the Initial and Ratoon Sorghum Crops

The fodder DMY of the initial and ratoon sorghum crops was significantly ($P < 0.05$) influenced by the AMPs and the variety, as shown in Table 5 ($P < 0.05$). Hybrid fodder sorghum demonstrated a significantly higher ($P < 0.05$) DMY when grown with narrow plant spacing in AMP2 and AMP4 treatments. These findings align with the results of Turgut *et al.* (2005), who observed greater fodder DMY with the intra-row spacing of 5 and 10 cm (30.1 and 31.0 MT/ha, respectively) compared to spacing of 15, 20, and 25 cm (28.4, 26.9, and 26.6 MT/ha, respectively) in forage sorghum. Malik *et al.* (2007) also reported higher fresh fodder yield with a narrow row spacing of 15 cm (57.36 MT/ha) compared to wider spacing of 30

and 45 cm (28.99, and 20.27 MT/ha, respectively). Considering the plant dry matter content (28.47%) the DMY could estimate to be 16.33 MT/ha at the narrow row spacing of 15 cm. In contrast, Manjunatha *et al.* (2014) observed significantly greater DMY in fodder sorghum with row spacing of 45 and 60 cm (36.28 and 35.18 MT/ha, respectively) compared to spacing of 30 cm (31.70 MT/ha). Additionally, they found the highest DMY (42.33 MT/ha) when the N fertilization rate was 300 kg/ha, whereas rates of 120, 180, and 240 kg/ha resulted in DMY of 25.99, 31.84 and 37.39 MT/ha, respectively.

Further, as observed in growth parameters, no significant ($P > 0.05$) differences were observed between management packages with high fertilizer rates with short irrigation intervals and low fertilizer rates with long irrigation intervals (AMP1 vs. AMP3 and AMP2 vs. AMP4) in DMY both in initial and ratoon crops.

The application of nutrient-balanced fertilizers enhances the growth and development of fodder sorghum crops, leading to increased fodder yield. By carefully determining the appropriate fertilizer rate and plant spacing, it is possible to achieve higher DMY in fodder sorghum (Shahrajabian *et al.*, 2011). The current investigation found that cultivating fodder sorghum with narrow spacing (AMP2 and AMP4) resulted in a higher LAI and subsequently greater DMY in both the initial and ratoon harvests (Table 2, Table 3, Table 4). Furthermore, the DMY of hybrid fodder sorghum cultivated at low or high plant density was not affected by the reduction of fertilizer rate by 75% and the extension of the irrigation interval (AMP2 vs. AMP4 and AMP1 vs. AMP3).

CONCLUSION

Hybrid fodder sorghum varieties cultivated at higher plant density, along with reduced fertilizer (75%) and irrigation, can yield comparable fodder yield (21.1 and 26.1 MT/ha, respectively) to those grown at lower plant density with more fertilizer and irrigation (24.6 and 28.1 MT/ha, respectively) in lowland paddy fields during Yala and third seasons in the dry zone.

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REFERENCES

- Afzal, M., Ahmad, A.U.H., Zamir, S.I., Khalid, F., Mohsin, A.U. and Gillani, S.M.W. (2012). Performance of multi-cut forage sorghum under various sowing methods and nitrogen application rates. *The Journal of Animal & Plant Sciences*, 23(1), 232-239.
- Central Bank of Sri Lanka. (2019). Annual Report 2019 — [WWW Document], URL <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2019> (accessed 11.19.23).
- Ayub, M., Nadeem, M.A., Tahir, M., Ghafoor, A. and Naeem, M. (2010). Comparative studies on the growth, forage yield and quality of sorghum (*Sorghum bicolor* L.) varieties under irrigated conditions of Faisalabad. *Pakistan Journal of Life and Social Sciences*, 8(2), 94-97.
- Berenguer, M.J. and Faci, J.M. (2001). Sorghum (*Sorghum bicolor* L. Moench) yield compensation processes under different plant densities and variable water supply. *European Journal of Agronomy*, 15, 43–55.
- Cho, N.K., Kang, Y.K., Song, C.K., Jeun, Y.C., Oh, J.S., Cho, Y.I. and Park, S.J. (2004). Effects of planting density on growth, forage yield and chemical composition of Jeju native Sorghum (*Sorghum bicolor* L.). *Journal of the Korean Society of Grassland and Forage Science*, 24, pp. 225–230.
- Dassanayake, A.R., De Silva, G.G.R. and Mapa, R.B. (2020). Major Soils of the Dry Zone and Their Classification, in: Mapa, R.B. (Ed.), *The Soils of Sri Lanka*, World Soils Book Series. Springer International Publishing, Cham, 49–67. DOI: https://doi.org/10.1007/978-3-030-44144-9_5
- Hussein, M.M. and Alva, A.K. (2014). Growth, yield and water use efficiency of forage sorghum as affected by NPK fertilizer and deficit irrigation. *American Journal of Plant Sciences*, 05, pp. 2134–2140. DOI: <https://doi.org/10.4236/ajps.2014.513225>
- Jahanzad, E., Jorat, M., Moghaddam, H., Sadeghpour, A., Chaichi, M. and Dashtaki, M. (2013). Response of a new and commonly grown forage sorghum cultivar to limited irrigation and planting density. *Agricultural Water Management*, 117, pp. 62–69. DOI: <https://doi.org/10.1016/j.agwat.2012.11.001>
- Mahmud, K., Ahmad, I. and Ayub, M. (2003). Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (*Sorghum bicolor* L.). *International Journal of Agriculture and Biology*, 5, pp. 61–63.
- Malik, M.F.A., Hussain, M. and Awan, S.I. (2007). Yield response of fodder sorghum (*Sorghum bicolor* L) to seed rate and row spacing under rain-fed conditions. *Journal of Agriculture and Social Sciences*, 3(3), pp. 95-97.
- Manjunatha, S.B., Angadi, V., Palled, Y., Hosamani, S., Babalad, H., Hosamani, M., Mudakavi, D. and Channal, H. (2014). Response of multi-cut fodder sorghum (CoFS-29) to row spacings and nitrogen levels under irrigated conditions*. *Karnataka Journal of Agricultural Sciences*, 26, pp. 511–513.
- Pradhan, J., Das, H., Kundu, C. and Bandyopadhyay, P. (2015). Response of fodder sorghum to irrigation scheduling and nitrogen levels. *International Journal of Farm Sciences*, 5(2), pp. 15-20, 2015.
- Punyawardena, B.V.R. (2010). Climate of the dry zone of Sri Lanka. Soils of the dry zone of Sri Lanka. *Special Publication*, (7), pp. 9-26.
- Raei, Y. and Sharifi, R.S. (2009). Effects of sowing date and plant density on forage yield of sorghum. *Agricultural Science (Tabriz)*, 19(1), pp. 116–129.
- Scott, S., Gordon, B., Taylor, R., Duncan, S. and Fjell, D. (1999). Narrow-row grain sorghum production in Kansas. Manhattan: Kansas State University, pp. 1-4.
- SEPC – Department of Agriculture Sri Lanka. (2019). URL <https://doa.gov.lk/sepc/> (accessed 11.19.23).
- SEPC – Department of Agriculture Sri Lanka. (2020). URL <https://doa.gov.lk/sepc/> (accessed 11.19.23).
- Shahrajabian, M.H., Soleymani, A. and Naranjani, L. (2011). Grain yield and forage characteristics of forage sorghum under different plant densities and nitrogen levels in second cropping after barley in Isfahan, Iran. *Research on Crops*, 12, pp. 68–78.

- Shahrajabian, M.H., Khoshkharam, M., Sun, W. and Cheng, Q. (2020). The influence of increased plant densities and nitrogen fertilizer levels on forage yield, seed yield and qualitative characteristics of forage sorghum (*Sorghum bicolor* L. Moench). *Thai Journal of Agricultural Science*, 53, pp. 201–217.
- Soleymani, A., Shahrajabian, M.H. and Naranjani, L. (2011). Study the effect of plant densities and nitrogen fertilizers on yield, yield components and grain protein of grain sorghum. *Journal of Food, Agriculture and Environment*, 9, pp. 244–246.
- Turgut, I., Bilgili, U., Duman, A. and Acikgoz, E. (2005). Production of sweet sorghum (*Sorghum bicolor* L. Moench) increases with increased plant densities and nitrogen fertilizer levels. *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, 55, pp. 236–240. DOI: <https://doi.org/10.1080/09064710510029051>
- Uzun, A., Bilgili, U., Sincik, M. and Açikgöz, E. (2004). Effects of seeding rates on yield and yield components of Hungarian vetch (*Vicia pannonica* Crantz.). *Turkish Journal of Agriculture and Forestry*, 28, pp. 179–182.
- Vasilakoglou, I., Dhima, K., Karagiannidis, N. and Gatsis, T. (2011). Sweet sorghum productivity for biofuels under increased soil salinity and reduced irrigation. *Field Crops Research*, 120, pp. 38–46. DOI: <https://doi.org/10.1016/j.fcr.2010.08.011>