DOI: 10.17138/TGFT(6)34-41

Research Paper

Evaluation of growth parameters and forage yield of Sugar Graze and Jumbo Plus sorghum hybrids under three different spacings during the *maha* season in the dry zone of Sri Lanka

Efecto de distancia de siembra en el desarrollo y rendimiento de dos híbridos de sorgo forrajero (Sugar Graze y Jumbo Plus) durante la temporada de maha *en la zona seca de Sri Lanka*

HAJAROOBA GNANAGOBAL AND JEYALINGAWATHANI SINNIAH

Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka. www.agri.jfn.ac.lk

Abstract

A field experiment to evaluate the growth parameters and fodder yields of Sugar Graze and Jumbo Plus under occasional irrigation was conducted at 3 different plant spacings (30 × 15, 30 × 45 and 30 × 60 cm) on a red-yellow latosol in the dry zone of Sri Lanka from August 2015 to January 2016. The design was a randomized block with 3 replications. Initial harvesting of fodder was done 60 days after planting and 2 ratoon yields were assessed at successive 60-day intervals. Plant spacing was inversely related (P<0.05) to dry matter (DM) yield with the narrowest spacing (30 × 15 cm) producing yields of 14.1 t DM/ha for Sugar Graze and 12.6 t DM/ha for Jumbo Plus at the initial harvest. Plant spacing also influenced leaf area, stem girth, root length and plant height in the initial harvest. Sugar Graze produced higher yields than Jumbo Plus at the initial and second ratoon harvests. Yields from ratoon crops were about 30% of those for the initial harvest. Further studies are needed to determine how these findings apply under the low-rainfall conditions of the *yala* season, and chemical analyses and animal feeding studies would provide valuable information on the nutritional value of the different forages.

Keywords: Dry matter yield, forage sorghum, ratoon crop, red yellow latosol, row width.

Resumen

En un latosol rojo-amarillo de la zona seca al norte de Sri Lanka entre agosto de 2015 y enero de 2016 se evaluaron algunas características de crecimiento y los rendimientos de forraje de los cultivares Sugar Graze y Jumbo Plus bajo riego ocasional usando 3 distancias de siembra (30 × 15, 30 × 45 y 30 × 60 cm). Los tratamientos se dispusieron en un diseño de bloque al azar con 3 repeticiones. La primera cosecha de forraje se realizó 60 días después de la siembra, seguida por 2 cosechas de rebrote a un intervalo de 60 días cada una. Los resultados mostraron que la distancia de siembra se relacionó de manera inversa (P<0.05) con el rendimiento de materia seca (MS), siendo este más alto (14.1 t MS/ha) en la distancia 30 × 15 cm en la primera cosecha para el cv. Sugar Graze en comparación con el cv. Jumbo Plus (12.6 t MS/ha). La distancia de siembra también influyó en el área foliar, el grosor del tallo, la longitud de las raíces y la altura de la planta en la primera cosecha. Sugar Graze produjo mayores rendimientos que Jumbo Plus en la primera cosecha y en la segunda cosecha de rebrote. Los rendimientos en las dos cosechas de rebrote fueron de alrededor del 30% de la primera cosecha. Se requieren estudios adicionales para determinar cómo se comparan estos resultados con los que se puedan obtener en época seca (temporada *yala*). Además, análisis químicos y estudios nutricionales con animales proporcionarían información valiosa sobre el valor nutritivo de los diferentes forrajes.

Palabras clave*:* Distancia entre surcos, latosol amarillo-rojo, rebrote, rendimiento de materia seca.

Correspondence: Dr. (Ms.) Jeyalingawathani Sinniah, Department of Animal Science, Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, 44000, Sri Lanka.
E-mail: jeyalingawathani@gmail.com

Introduction

High performance of farm animals, especially dairy cows, depends on the availability of adequate amounts of quality fodder and in developing countries, inadequacy of quality forage is the critical limitation to profitable animal production (Sarwar et al. 2002). Among the many options for overcoming the shortage of forage, the introduction of high-yielding crop varieties ranks highly (Bilal et al. 2001). However, in many developing countries, because of the ever-growing need for food for humans, only limited cultivated land can be allocated to produce fodder for livestock. Douglas (1980) recommended annual summer crops such as forage sorghum hybrids (*Sorghum* spp.) for use as alternative forage crops in drier areas in order to bridge the feed shortage gap.

Sugar Graze, a sweet sorghum × sweet sorghum hybrid, is a popular forage source among the livestock farmers of Sri Lanka and Jumbo Plus, a sweet sorghum × Sudan grass hybrid, is still in the initial stages of introduction. Sugar Graze is a late-flowering cultivar with high yields, a crude protein (CP) concentration of 12–18% and a high sugar content that boosts feed quality and palatability, resulting in minimal feed wastage. In addition, the crop is resistant to a wide range of diseases. Mature Sugar Graze promotes good weight gains and provides adequate energy for livestock (Pacific Seeds 2009). Jumbo Plus, a forage sorghum hybrid cultivar, has excellent re-growth potential and high productivity and is adapted to both dryland and irrigated situations. It has similar CP concentration to Sugar Graze with 56–64% dry matter (DM) digestibility when the plant is 55–60 days old or at 5–10% flowering stage and can be used for grazing, silage making and rotational cropping (Forage Sorghum Guide 2015).

These crops have the potential to compete favorably with maize silage in terms of yield and nutritive value (Ketterings et al. 2005) and may be an appropriate alternative to maize for utilizing irrigation water in drought-prone areas. The shortage of ground water is the primary limitation to cultivating grass in the dry zone. As such, it is essential to select a drought-tolerant grass/fodder species, and Sri Lankan farmers cultivate fodder sorghum. In an initial study 7 cuttings were achieved from a single planting yielding 24 kg of fresh fodder/m^2 from a single cutting with plant spacing of 45 × 15 cm (Sivayoganathan 2016). While research on sorghum cultivars in Pakistan has shown marked differences between cultivars in green fodder yield and morphology under 30 cm row spacing (Bakhsh et al. 2015), similar data on forage sorghum hybrid cultivars in the dry zone of Sri Lanka are limited. There is a need to assess the growth of these cultivars and how varying the plant spacing affects both yield and quality of forage so that the growing demand for forage by livestock can be met.

The present study was designed to determine the crop morphology, growth parameters and forage yield of Sugar Graze and Jumbo Plus under irrigation in the dry zone of Sri Lanka under 3 different plant spacings (30 × 15, 30 × 45 and 30 × 60 cm).

Materials and Methods

This experiment was carried out at the livestock farm, Department of Animal Science, Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi (Figure 1), from August 2015 to January 2016. These months fall into Sri Lanka's *maha* season, i.e. the period September – February which experiences rainfall through the Northeast monsoon.

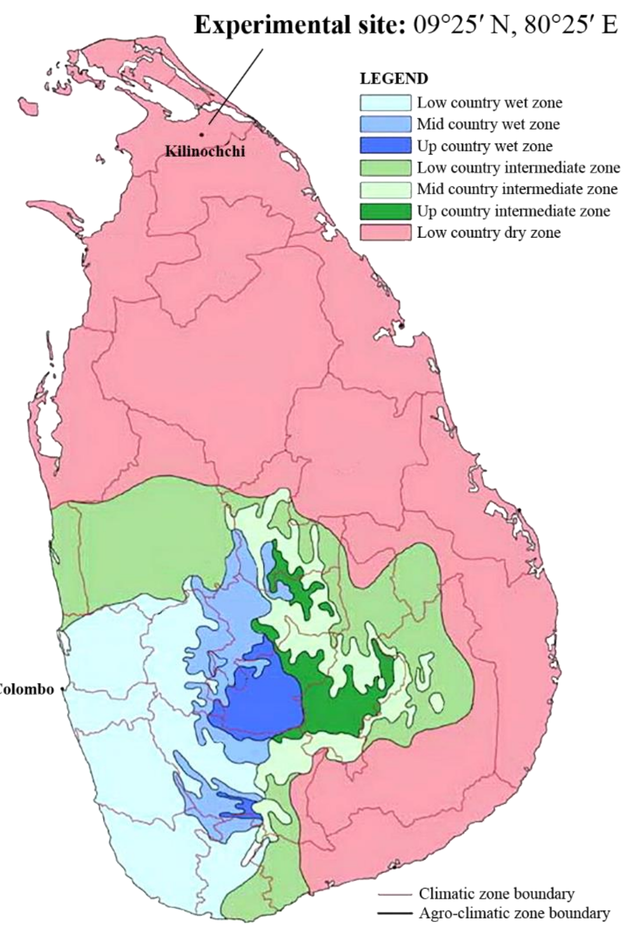

Figure 1. The experimental site, Kilinochchi District, in the dry zone of Sri Lanka.

The remaining period of the year is dry with the driest period being June to August. During the study period (August 2015–January 2016), rainfall in individual months varied greatly (Figure 2) and due to the extremely low water retention capacity irrigation had to be applied in some months.

According to Vavuniya meteorological data, the average monthly temperature in the region is 28.4 °C (range 25.6–30.0 °C), while maximum and minimum averages are 35.0 and 21.3 °C, respectively (Jaffna and Kilinochchi Water Supply and Sanitation Project 2010).

Soils of the area are red-yellow latosols (Haplustox), which are the most intensively cultivated soils of Jaffna Peninsula and have very low inherent fertility. Extremely poor water retention properties mean that dryland cropping is inappropriate, while conventional flood irrigation is impractical owing to very rapid infiltration and soil drying.

The experiment was laid out in a completely randomized design (CRD) in a factorial arrangement of 3 plant spacings (30 × 15, 30 × 45 and 30 × 60 cm) and 2 cultivars (Sugar Graze and Jumbo Plus) with 3 replications. Sowing was on 5 August 2015.

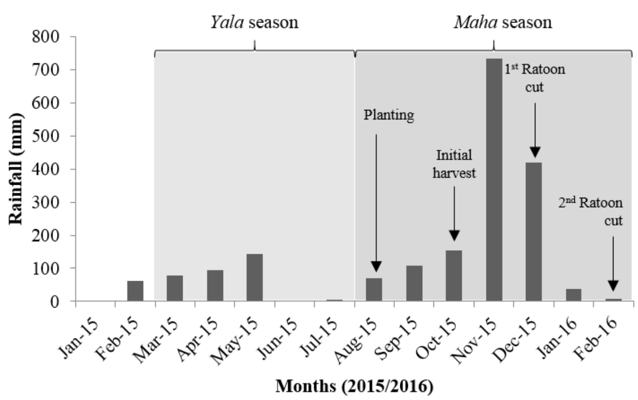

Figure 2. Monthly rainfall of Kilinochchi District from January 2015 to February 2016. Source: Department of Census and Statistics of Sri Lanka (2015); Kilinochchi District (2016).

Within rows spacing was kept constant at 30 cm and the spacing between rows was varied. Seeds were sown at the rate of 2 seeds per hill and seedlings were thinned to a single plant per hill 2 weeks after sowing resulting in plant populations of approximately 222,000, 74,000 and 55,000 plants/ha for inter-row spacings of 15, 45 and 60 cm, respectively. Cattle manure was applied at planting at the rate of 100 kg/ha (N: 1.2–1.9%, P: 0.2–0.5%, K: 0.5–1.1%) and inorganic fertilizers were applied 1 week after establishment of plants at the rate of 50 kg urea, 25 kg triple superphosphate and 12.5 kg muriate of potash/ha. During the dry spell of the study period, irrigation was done at weekly intervals. Plots were manually weeded at 30 days after planting to reduce competition from weeds.

Five plants were randomly selected from each plot for recording of leaf length and width, leaf area [leaf area factor (0.72 for forage sorghum) × length × width] (Arkel 1978), number of leaves per plant, stem girth, root length from the base of the plant to tip of the selected average lengthier rootlet, internodal elongation and plant height at weekly intervals. At 60 days after planting, on 3 October 2015, the crops were cut 15 cm from ground level and allowed to ratoon. Two ratoon cuts were made at 60-day intervals, on 1 December 2015 and 29 January 2016. Immediately after harvesting, fresh forage was weighed using a spring balance. Samples (approximately 2 kg) of the harvested forage from each experimental plot were selected and air-dried for 24 hours, followed by oven-drying at 75 °C for 72 h to constant weight for dry matter yield determination. Data were subjected to Analysis of Variance and mean separation was done with Duncan's multiple range test ($P \leq 0.05$) (Duncan 1955) with SPSS (Statistical Package for Social Science) version 16.0 for Windows.

Results

Initial harvest

For the initial harvest the 2 cultivars generally responded differently to variation in plant spacing in terms of plant morphology (Table 1).

While leaf length, leaf width and leaf area were unaffected by plant spacing for Jumbo Plus, the narrow spacing (30 × 15 cm) produced narrower leaves with smaller area than the medium (30 × 45 cm) and wide (30 × 60 cm) spacings for Sugar Graze. Similarly, the narrow and wide spacings for Jumbo Plus produced more leaves per plant than the medium spacing, while the medium spacing for Sugar Graze produced more leaves than the narrow spacing. In general, the thickest stems were produced at the wide spacing and the thinnest at the narrow spacing.

A similar trend occurred with root length with longer root lengths generally being associated with wide plant spacing and shorter root lengths with narrow spacing. Plant height was unaffected by spacing for Jumbo Plus, while the wide spacing for Sugar Graze produced the tallest plants.

Overall, Sugar Graze displayed slightly longer, wider leaves with much greater area than Jumbo Plus but produced fewer leaves, though differences were not significant. This cultivar also produced longer roots than

Table 1. Effects of row spacing (30 x 15, 30 x 45, 30 x 60 cm) on growth parameters and yields of Sugar Graze and Jumbo Plus 60 days after planting (initial harvest).

Parameter	Sugar Graze			Jumbo Plus		
	30 × 15	30 × 45	30 × 60	30 × 15	30 × 45	30 × 60
Leaf length (cm)	90.6 ± 4.92a	91.4 ± 2.17a	92.8 ± 2.69a	86.5 ± 3.52a	89.5 ± 2.19a	87.6 ± 3.11a
Leaf width (cm)	8.6 ± 0.86b	9.2 ± 0.80a	9.2 ± 0.67a	7.27 ± 0.64a	7.37 ± 0.83a	7.15 ± 0.91a
Leaf area (cm^2)	560 ± 64.5b	608 ± 61.1a	616 ± 48.8a	443 ± 36.6a	463 ± 66.7a	473 ± 67.9a
Number of leaves/plant	13.0 ± 0.93b	13.9 ± 0.83a	13.3 ± 0.96ab	15.0 ± 0.93a	13.7 ± 0.90b	15.1 ± 1.68a
Stem girth (cm)	5.50 ± 0.38b	6.23 ± 0.86a	6.65 ± 0.62a	5.65 ± 0.52b	6.03± 0.77b	6.57 ± 0.46a
Root length (cm)	23.5 ± 0.01c	28.3 ± 0.01a	26.0 ± 0.01b	22.3 ± 0.01c	24.3 ± 0.01b	25.6 ± 0.01a
Internodal elongation (cm)	21.9 ± 2.54a	20.6 ± 1.95a	21.4 ± 2.41a	20.8 ± 1.77a	22.7 ± 1.16a	23.2 ± 1.95a
Plant height (cm)	227 ± 22.7b	239 ± 40.6b	278 ± 18.5a	290 ± 14.8a	292 ± 14.3a	297 ± 25.4a
Dry matter yield (t/ha)	14.1 ± 2.60a	11.4 ± 1.94b	11.3 ± 1.80b	12.6 ± 2.77a	9.2 ± 2.81ab	6.3 ± 1.71b

Each value is a mean ± SD for 3 replicates.
Within rows and cultivars, means without a common letter differ ($P \leq 0.05$).

Jumbo Plus but internodal elongation was greater for Jumbo Plus, resulting in taller plants.

Dry matter (DM) yields were inversely related to plant spacing with yield decreasing progressively as plant spacing increased, although differences were not always significant. Sugar Graze produced higher DM yields than Jumbo Plus (Table 1).

First ratoon crop

In the first ratoon crop some parameters, viz. leaf length, number of leaves and plant height, were not influenced by spacing in either cultivar, while leaf width, leaf area, internodal elongation and stem girth varied inconsistently with row spacing in the 2 cultivars (Table 2). Varietal differences also were noted among the morphological parameters of the first ratoon crop, where generally leaf length and width, leaf area, number of leaves per plant and stem girth were greater for Sugar Graze, while Jumbo Plus showed higher values for internodal elongation and plant height.

Dry matter yields followed similar trends in both cultivars with declining yields as plant spacing increased, but differences were not always significant (Table 2). Varietal differences in DM yield were small.

Second ratoon crop

As for the first ratoon crop, row spacing had no significant effect on leaf width, leaf area and stem girth in either cultivar, while inconsistent responses occurred for the remaining morphological parameters (Table 3). There were consistent effects of row spacing on DM yields in both cultivars with yields declining as plant spacing increased, but differences were significant ($P<0.05$) only for Jumbo Plus. Dry matter yields for Jumbo Plus at the medium and wide spacings declined dramatically to about half those for Sugar Graze. Overall, increases in row spacing resulted in greater percentage yield decreases in Jumbo Plus than in Sugar Graze. Yields for both ratoon crops were generally about 25–35% of those obtained at the initial harvest.

Table 2. Effects of row spacing (30 x 15, 30 x 45, 30 x 60 cm) on growth parameters and yields of first ratoon crop of Sugar Graze and Jumbo Plus.

Parameter	Sugar Graze			Jumbo Plus		
	30 × 15	30 × 45	30 × 60	30 × 15	30 × 45	30 × 60
Leaf length (cm)	78.3 ± 5.07a	72.7 ± 20.2a	78.1 ± 3.93a	71.3 ± 4.78a	71.4 ± 5.28a	70.0 ± 5.49a
Leaf width (cm)	6.79 ± 0.70a	6.01 ± 0.66b	6.37 ± 0.52ab	4.19 ± 0.41b	4.57 ± 0.34a	4.45 ± 0.49ab
Leaf area (cm^2)	382 ± 50.7a	317 ± 100b	358 ± 39.1ab	215 ± 29.4a	234 ± 22.8a	224 ± 35.6a
Number of leaves/plant	9.87 ± 0.83a	9.53 ± 1.25a	10.3 ± 1.03a	9.33 ± 1.18a	9.53 ± 1.13a	8.67 ± 1.50a
Stem girth (cm)	5.15 ± 0.36a	4.45 ± 0.34b	4.63 ± 0.45b	3.83 ± 0.37a	3.88 ± 0.15a	3.63 ± 0.21b
Internodal elongation (cm)	16.1 ± 4.07a	17.8 ± 2.62a	17.5 ± 2.17a	16.9 ± 3.32b	19.6 ± 2.16a	21.1 ± 1.18a
Plant height (cm)	115 ± 19.9a	115 ± 13.0a	119 ± 14.6a	131 ± 15.8a	138 ± 11.6a	139 ± 17.4a
Dry matter yield (t/ha)	3.36 ± 0.531a	2.95 ± 0.614a	2.36 ± 0.416a	3.84 ± 0.511a	3.27 ± 0.309a	2.13 ± 0.483b

Each value is a mean ± SD for 3 replicates.
Within rows and cultivars, means without a common letter differ ($P \leq 0.05$).

Table 3. Effects of row spacing (30 x 15, 30 x 45, 30 x 60 cm) on growth parameters and yields of second ratoon crop of Sugar Graze and Jumbo Plus.

Parameter	Sugar Graze			Jumbo Plus		
	30 × 15	30 × 45	30 × 60	30 × 15	30 × 45	30 × 60
Leaf length (cm)	62.7 ± 6.15a	59.0 ± 3.58a	57.5 ± 13.1a	60.7 ± 5.57a	51.5 ± 7.15b	54.5 ± 4.63ab
Leaf width (cm)	5.78 ± 0.78a	5.73 ± 0.82a	5.65 ± 0.98a	3.63 ± 0.47a	3.68 ± 0.62a	4.13 ± 0.38a
Leaf area (cm^2)	262 ± 50.7a	244 ± 45.4a	239 ± 89.0a	158 ± 18.5a	137 ± 35.0a	162 ± 21.7a
Number of leaves/plant	7.00 ± 0.63b	7.00 ± 0.01b	8.33 ± 0.52a	6.00 ± 0.63a	6.00 ± 0.63a	6.66 ± 0.82a
Stem girth (cm)	4.50 ± 0.55a	4.25 ± 0.42a	4.08 ± 0.38a	3.17 ± 0.26a	3.20 ± 0.32a	3.36 ± 0.22a
Internodal elongation (cm)	20.0 ± 2.83a	22.1 ± 2.13a	19.0 ± 1.95b	25.2 ± 3.95a	26.7 ± 3.36a	24.4 ± 2.48a
Plant height (cm)	190 ± 17.2a	178 ± 10.2ab	167 ± 10.1b	191 ± 9.12a	182 ± 8.91a	168 ± 9.31b
Dry matter yield (t/ha)	4.47± 0.744a	3.29 ± 1.090a	2.85 ± 0.350a	4.33 ± 0.358a	1.77 ± 0.206b	1.42 ± 0.539b

Each value is a mean ± SD for 3 replicates.
Within rows and cultivars, means without a common letter differ (P≤0.05).

Discussion

Leaf length and width

Leaf development has been described extensively for fodders, as growth is mostly reflected in large increases in leaf length as plants grow to maturity, accompanied by relatively small increases in width and thickness (Skinner and Nelson 1994). Large leaf lengths are also important for the survival of individual plants within a sward (Barre et al. 2015). Leaf length and width values observed for both cultivars during the present study were slightly greater than the values recorded by Singh et al. (2014) for leaf length (45–70 cm) and width (4–7 cm) of sorghum hybrids. Leaf length of Sugar Graze was similar to the 95 ± 2.0 cm reported by Pahuja et al. (2014) in India, for the first cut at 50% flowering and a spacing of 15 × 45 cm, whereas leaf width was slightly higher than that recorded by the same authors (6 ± 0.58 cm).

Leaf area

The results of the present study demonstrate that leaf area increases as plant spacing increases as shown by Lamana (2007). This could be due to less competition among plants for space and soil nutrients as the plant population per unit area decreased. Therefore, the lower population density which resulted from the wider plant spacing gives better conditions for more accumulation of photosynthetic products, better growth and expansion of foliage, which was in turn expressed in greater DM yields. The range of values for leaf area (440–615 cm^2) for Sugar Graze and Jumbo Plus in the present study were in agreement with the values reported by Nabi et al. (2006) for advanced lines of forage sorghum cultivars. The higher mean leaf area in Sugar Graze (595 ± 62.3 cm^2) than in Jumbo Plus (460 ± 58.9 cm^2) may be due to differences in genetic makeup of the cultivars. Musa et al. (1993), Naeem et al. (2002), Mahmud et al. (2003) and Chohan et al. (2003; 2006) also observed variation in leaf area among various cultivars and varieties of forage sorghum.

Number of leaves per plant

The general absence of any consistent effect of row spacing on leaf number per plant is in agreement with the findings of Liu et al. (2004), who observed for maize that it did not affect leaf number. In contrast Lamana (2007) reported that wider plant spacing in maize had a positive effect on number of leaves. The values recorded for number of leaves per plant for both cultivars in the present study were consistent with those of Monteiro et al. (2012), who reported that number of leaves in forage sorghum is generally between 14 and 17. Chohan et al. (2003) and Naeem et al. (2002) also reported variation among different cultivars of sorghum for number of leaves per plant.

Stem girth

Stem girth recorded in the present study was similar to that reported by Pahuja et al. (2014) in India for stem girth of Sugar Graze (5.9 ± 0.21 cm at 50% flowering stage and 15 × 45 cm spacing). While Yosef et al. (2009) and Ayub et al. (1999) found significant variation in stem diameter among different cultivars of sorghum, cultivar differences in our study were not statistically significant (P>0.05).

Root length

The trend for root length to increase as row spacing increased would reflect greater competition between plants at the narrower spacings. Despite the shorter root length per plant at the narrow spacing, the much greater plant populations at this spacing would have resulted in substantially greater root length per unit area than at the wider spacings. As a result plants at the narrow spacing would have had better opportunity to utilize soil water and nutrients than at wider spacing, resulting in higher DM yields.

Internodal elongation and plant height

Plant height as a growth parameter is a result of elongation of the stem internodes, which is influenced by the environment as suggested by Weston (1967). In the current study taller plants were observed with wider spacing, which contrasts with reports in the literature that narrower spacing will give taller plants as a result of competition for sunlight (Lamana 2007). However, the absence of any effect of plant spacing on plant height of Jumbo Plus supports the finding of Roy and Biswas (1992) that plant height at maturity was not affected by plant spacing. The significant differences in plant height between the 2 cultivars may be due to genotypic variation, as differences in internodal elongation between varieties can lead to differences in height as reported by Evans (1975) and Weston (1967). Nabi et al. (2006) and Silungwe (2011), who worked with different forage sorghum cultivars, also reported plant heights (203–230 cm) lower than those in the present study (227–298 cm), as did Pahuja et al. (2014) for Sugar Graze (189 ± 1.9 cm) in India.

Dry matter yield

Plant spacing has a marked impact on the efficiency of use of land, light, water and nutrients. By optimizing plant spacing, highest yield potential can be achieved from the smallest possible area (Oseni and Fawusi 1986). The direct relationship between DM yield and plant population agrees with the findings of Fisher and Wilson (1975), who reported greater DM yield with higher plant populations than with lower plant populations. Wolf et al. (1993) and Graybill et al. (1991) also reported that DM yield of forage maize responded positively to plant density. This relationship would be affected by the availability of soil moisture, and the application of irrigation on a regular basis in this study would have ensured that all row spacings/plant populations had adequate water. Dry matter yield recorded for Sugar Graze in the current study seemed to be less affected by differences in row spacing than Jumbo Plus, which appeared not to be related to root length as there were no significant differences in root length between the cultivars. Epasinghe et al. (2012) reported DM yields of Sugar Graze in Sri Lanka of 5,230 kg/ha at 60 days after planting at 45 × 15 cm spacing and these lower yields might be attributed to the differences in the spacing, soil fertility and environmental conditions. By contrast Nabi et al. (2006) recorded yields of 10,400–13,100 kg DM/ha for advanced lines of forage sorghums and Silungwe (2011) recorded 13,262 kg DM/ha at 15 cm row spacing 78 days after sowing for Sugar Graze.

Forage yield is a function of growth parameters, viz. plant population, plant height, leaf:stem ratio, leaf area, and leaf area index (Lamana 2007). The differences in DM yield between the 2 cultivars could be attributed to the fact that Sugar Graze exceeded Jumbo Plus in the growth parameters leaf length and width, leaf area and root length. Watson (1947) has shown that variation in total dry weight of plants is more dependent on variation in leaf area. Light interception capacity of the leaf is amplified with the increase in leaf area often leading to increase in photosynthesis and DM yield. Therefore, higher DM yield recorded for Sugar Graze might be attributed to its higher leaf area than Jumbo Plus.

First and second ratoon crops

The most consistent findings with the ratoon crops were that there were fewer leaves per plant, leaves were smaller, height was less and DM yields were lower than for the initial harvest. However, DM yield remained a factor of plant spacing with higher yields at narrower row spacing, indicating that plants were still accessing moisture and nutrients from the soil in sufficient quantities to maintain acceptable growth levels. The reduced yields are possibly a function of nutrient supply in the soil being depleted by the initial crop and a change in seasonal conditions over time. There were no significant differences between Sugar Graze and Jumbo Plus in DM yields for the first ratoon crop, in contrast with the generally higher yields for Sugar Graze in the initial crop and second ratoon crop. Despite having smaller leaves and thinner stems than Sugar Graze, the greater height of Jumbo Plus ensured that yields in the 2 cultivars were similar. The success of the second crop is often a function of how early the main crop was planted and harvested, which determines the seasonal conditions under which the first and second ratoon crops must grow. However, normally ratoon crops of sorghum are expected to yield from 25 to 35% of the main crop (Livingston and Coffman 1996), and our yields fall within this range. Significant differences in DM yield between main and ratoon crops have been reported by Saberi and Aishah

(2014), when assessing yield responses of forage ratoon sorghum under varying salinity levels and irrigation frequencies.

Our findings suggest that both Sugar Graze and Jumbo Plus will grow satisfactorily under irrigation in this environment. While DM yields from the first harvest were excellent, yields from the ratoon crops were significantly lower despite the application of irrigation. A plant spacing of 30 × 15 cm produced the highest yields but results under rain-fed conditions would not necessarily be the same. Further studies to determine the performance in the low-rainfall (*yala*) season are necessary to determine desirable spacings under such dry conditions. Chemical analyses of forage and digestion studies would provide valuable information on the relative merits of these two cultivars for livestock feeding.

References

Arkel HV van. 1978. Leaf area determinations in sorghum and maize by the length-width method. Netherlands Journal of Agricultural Science 26:170–180.

Ayub M; Tanveer A; Mahmud K; Ali A; Azam M. 1999. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (*Sorghum bicolor* L.). Pakistan Journal of Biological Science 2:247–250. DOI: 10.3923/pjbs.1999.247.250

Bakhsh A; Zahid MS; Shafeeq S; Gurmani ZA; Khan S. 2015. Comparison of green fodder yield in sorghum varieties under rainfed conditions of Islamabad. Life Sciences International Journal 9:3146–3149. goo.gl/GUCEdg

Barre P; Turner LB; Escobar-Gutiérrez AJ. 2015. Leaf length variation in perennial forage grasses (Review). Agriculture 5:682–696. DOI: 10.3390/agriculture5030682

Bilal MQ; Abdullah M; Lateef M. 2001. Effect of Mott dwarf elephant grass (*Pennisetum purpureum*) silage on dry matter intake, milk production, digestibility and rumen characteristics in Nili-Ravi buffaloes. Proceedings of 54th Annual Reciprocal Meat Conference, Vol. II, Indianapolis, IN, USA. p. 24–28.

Chohan MSM; Naeem M; Khan AH; Salah-ud-Din S. 2003. Performance of newly developed forage varieties of sorghum (*Sorghum bicolor* (L.) Moench). Asian Journal of Plant Sciences 2:48–50. DOI: 10.3923/ajps.2003.48.50

Chohan MSM; Naeem M; Khan AH; Kainth RA. 2006. Performance of pearl millet (*Pennisetum americanum*) varieties for green fodder yield. Journal of Agricultural Research 44:23–27. goo.gl/BqYrDJ

Department of Census and Statistics of Sri Lanka. 2015. Monthly rainfall in district (Kilinochchi) 2012–2015. goo.gl/xeAUhj

Douglas J. 1980. Yield of crops for forage and fodder. In: Drew KR; Fennessy PF, eds. Supplementary feeding. Occasional Publication No. 7. New Zealand Society of Animal Production, Mosgiel, New Zealand. p. 1–47.

Duncan DB. 1955. Multiple range and multiple F tests. Biometrics 11:1–42. DOI: 10.2307/3001478

Epasinghe TM; Jayawardena VP; Premalal GGC. 2012. Comparison of growth, yield and nutritive value of maize, multi-cut fodder sorghum and hybrid Napier (var. Co3) grown in wet zone of Sri Lanka. In: Kodithuwakku SP; Himali SMC, eds. Proceedings of 22nd Annual Students Research Session. Department of Animal Science, University of Peradeniya, Sri Lanka, 30 November 2012. p. 23. goo.gl/Ri3AFR

Evans LT. 1975. The physiological basis of crop yield. In: Evans LT, ed. Crop physiology, some case histories. Cambridge University Press, Cambridge, UK. p. 327–335.

Fisher KS; Wilson GL. 1975. Studies of grain production in *Sorghum bicolor* (L.) Moench. V. Effect of planting density on growth and yield. Australian Journal of Agricultural Research 26:31–41. DOI: 10.1071/ar9750031

Forage Sorghum Guide. 2015. goo.gl/ALg81T (accessed 25 December 2016).

Graybill JS; Cox WJ; Olis DJ. 1991. Yield and quality of forage maize as influenced by hybrid and planting date and plant density. Agronomy Journal 83:559–564. DOI: 10.2134/agronj1991.00021962008300030008x

Jaffna and Kilinochchi Water Supply and Sanitation Project. 2010. Jaffna and Kilinochchi Water Supply and Sanitation Project: Initial environmental examination. Asian Development Bank, Metro Manila, Philippines. goo.gl/jCkAtK

Ketterings QM; Godwin G; Cherney JH; Kilcer TF. 2005. Potassium management for brown midrib sorghum x sudangrass as replacement for corn silage in the North-eastern USA. Journal of Agronomy and Crop Science 191:41–46. DOI: 10.1111/j.1439-037x.2004.00144.x

Kilinochchi District. 2016. Rainfall pattern of district. Performance report and annual accounts - 2016. Kilinochchi, NP, Sri Lanka. p. 12. goo.gl/SS6fUx

Lamana MCL. 2007. Effect of spacing between plants on growth and forage yield of two maize (*Zea mays* L.) cultivars. M.Sc. Thesis. University of Khartoum, Khartoum, Sudan. goo.gl/fGnqfx

Liu W; Tollenaar M; Stewart G; Deen W. 2004. Within-row plant spacing variability does not affect corn yield. Agronomy Journal 96:275–280.goo.gl/HgDKYZ

Livingston SD; Coffman CG. 1996. Ratooning grain sorghum on the Texas Gulf Coast. Texas Agricultural Extension Service. The Texas A&M University System, College Station, TX, USA. hdl.handle.net/1969.1/87772

Mahmud K; Ahmad I; Ayub M. 2003. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum (*Sorghum bicolor* L.) cultivars. International Journal of Agricultural Biology 5:61–63. goo.gl/5kQMRk

Monteiro JST; Havrland B; Ivanova T. 2012. Sweet Sorghum (*Sorghum bicolor* (L.) Moench) bioenergy value – Importance for Portugal. Agricultura Tropica et Subtropica 45:12–19. DOI: 10.2478/v10295-012-0002-y

Musa M; Gondal MR; Ali A; Ashraf M. 1993. Effect of cutting at different plant growth stages and heights above ground levels on green fodder and dry matter yields of Sadabahar. Journal of Agricultural Research 31:409–413.

Nabi CG; Riaz M; Ahmad G. 2006. Comparison of some advanced lines of *Sorghum bicolor* (L.) Moench for green fodder/dry matter yield and morpho-economic parameters. Journal of Agricultural Research 44:191–196. goo.gl/imqKrC

Naeem M; Chauhan MSM; Khan AH; Salahaddin S. 2002. Evaluation of different varieties of sorghum for green fodder yield potential. Asian Journal of Plant Sciences 1:142–143. DOI: 10.3923/ajps.2002.142.143

Oseni TO; Fawusi MO. 1986. Influence of nursery spacing and plant arrangement on growth and leaf nutrient content of three citrus root stock seedlings. Tropical Agriculture 64:41–45. goo.gl/g5rVQW

Pacific Seeds. 2009. Sugar Graze for grazing, winter stand over and pit silage. goo.gl/zMvyLV (accessed 25 December 2015).

Pahuja S; Arya S; Kumari S; Panchta R. 2014. Evaluation of forage sorghum hybrids [*Sorghum bicolor* (L.) Moench]. Forage Research 40:159–162. goo.gl/4BCD3W

Roy SK; Biswas PK. 1992. Effect of plant density and detopping following silking on cob growth, fodder and grain yield of maize (*Zea mays*). The Journal of Agricultural Science 119:297–301. DOI: 10.1017/s0021859600012156

Saberi AR; Aishah HS. 2014. Physiological effects on re-growth of forage sorghums ratoon crop under varying salinity and irrigation frequency. British Journal of Applied Science & Technology 4:2277–2289. DOI: 10.9734/bjast/2014/5738

Sarwar M; Khan MA; Iqbal Z. 2002. Feed resources for livestock in Pakistan. International Journal of Agriculture & Biology 4:186–192. goo.gl/X2TVR2

Silungwe D. 2011. Evaluation of forage yield and quality of sorghum, sudangrass and pearl millet cultivars in Manawatu. M.Sc. Thesis. Massey University, Palmerston North, New Zealand. hdl.handle.net/10179/3234

Singh PK; Gautam RK; Roy SD; Singh AK; Ahmed SKZ. 2014. Performance of sorghum varieties for fodder yield during Rabi season in Andaman & Nicobar Islands. Journal of the Andaman Science Association 19:174–176. goo.gl/Db94KU

Sivayoganathan B. 2016. The SOLID approach to producing year-round cattle feed. United States Agency for International Development (USAID), Colombo, Sri Lanka. goo.gl/k1wvpW

Skinner RH; Nelson CJ. 1994. Role of leaf appearance rate and the coleoptile tiller in regulating tiller production. Crop Science 34:71–75. DOI: 10.2135/cropsci1994.0011183x003400010013x

Watson D. 1947. Comparative physiological studies on the growth of field crops. II. The effect of varying nutrient supply on net assimilation rate and leaf area. Annals of Botany 11:375–407. jstor.org/stable/42907023

Weston RH. 1967. Factors limiting the intake of feed by sheep. II. Studies with wheaten hay. Australian Journal of Agricultural Research 18:983–1002. DOI: 10.1071/ar9670983

Wolf DP; Coors TG; Albrecht KA; Undersonder DJ; Carter PR. 1993. Agronomic evaluations of maize genotypes selected for extreme fibre concentration. Crop Science 33:1359–1365. DOI: 10.2135/cropsci1993.0011183x003300060047x

Yosef E; Carmi A; Nikbachat M; Zenou A; Umiel N; Miron J. 2009. Characteristics of tall *versus* short-type varieties of forage sorghum grown under two irrigation levels, for summer and subsequent fall harvests, and digestibility by sheep of their silages. Animal Feed Science and Technology 152:1–11. DOI: 10.1016/j.anifeedsci.2009.01.018

(Received for publication 14 February 2017; accepted 29 September 2017; published 31 January 2018)