Response of forage sorghums Millo Blanco and Greenleaf sudangrass and their hybrids to planting dates[1]

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ABSTRACT

Forage sorghums Millo Blanco (MB) [*Sorghum bicolor* (L.) Moench] and ATx623 × MB (photoperiod sensitive) (PS) and Greenleaf (GL) sudangrass [*S. sudanense* (Piper) Stapf] and ATx623 × GL (photoperiod insensitive) (PI) were planted the 15th day of each month over a period of two years at the Isabela, P.R., USDA-ARS farm. Two consecutive 60-d harvests were made for each planting during a period of two years. Mean annual dry matter yield (DMY) in t/ha was 32 for ATx623 × MB, 29 for MB, 26 for ATx623 × GL, and 20 for GL. On the average, the PS genotypes had significantly higher DMY (32%) than the PI genotypes; and produced significantly more DM (96%) when planted in June than when planted in December. ATx623 × GL and ATx623 × MB significantly surpassed their male parents in DMY (33 and 11%). Mean forage crude protein (CP) of the genotypes was 11%. Significantly more crude protein yield (CPY) was obtained when the PS genotypes were planted during long days. Genotypes planted during short days were shorter. In most cases, leaf area was greater for the June to August plantings. Planting date (PD) had no significant effect on the in vitro dry matter digestibility (IVDMD) of the genotypes; the overall mean was 56%. This research demonstrated that DMY of more than 7 t/ha with a CP of 11% and IVDMD of 56% can be obtained in a 60-day growth period from a forage sorghum such as MB or ATx623 × MB planted during long days (June) in Puerto Rico. Results showed the advantage of planting PS lines and hybrids for forage production in Puerto Rico.

Key words: cytoplasmic male-sterility, photoperiod sensitivity, genotypes, dry matter yield, crude protein, leaf area.

RESUMEN

Respuesta de sorgos forrajeros Millo Blanco y pasto sudan Greenleaf y sus híbridos a épocas de siembra

La línea androestéril ATx623 [*Sorghum bicolor* (L.) Moench] se cruzó con Millo Blanco (MB), sensitivo al fotoperiodo (PS) y el pasto sudan Greenleaf (GL) [*S. sudanense* (Piper) Stapf], insensitivo al fotoperiodo (PI). Los híbridos F_1 y sus parentales se sembraron el día 15 de cada mes durante 1990 y

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1991 en la finca del USDA-ARS, Isabela, P.R. Los genotipos se cosecharon dos veces consecutivas a intervalos de 60 días. El rendimiento anual de materia seca (DMY) en t/ha fue 32 para ATx623 × MB, 29 para MB, 26 para ATx623 × GL y 20 para GL. En promedio, el DMY de los genotipos PS fue 32% mayor que el de los PI. Los genotipos PS produjeron 96% más forraje seco cuando se sembraron en junio que cuando se sembraron en diciembre. El DMY de los híbridos ATx623 × MB y ATx623 × GL fue 33 y 11% más alto que el de sus respectivos padres. La proteína cruda (CP) promedio fue de aproximadamente 11% en todos los genotipos. Se obtuvo rendimientos de CPY significativamente superiores, y las plantas fueron más altas cuando los genotipos PS se sembraron durante los días largos comparados con las siembras en días más cortos. En la mayoría de los casos, el área foliar fue mayor en las siembras de junio a agosto. La fecha de siembra no afectó significativamente la digestibilidad aparente in vitro (IVDMD), la cual promedió 56% entre genotipos. Este estudio demostró que en Puerto Rico es posible obtener DMY de 7 t/ha con un CP de 11% y un IVDMD de 56% cuando MB o ATx623 × MB se siembran durante los días largos (junio).

INTRODUCTION

In 1995-96, returns from livestock enterprises were $410 million or 60% of the total farm income in Puerto Rico (FFAPR, 1996). The island's dairy industry depends mostly on the use of imported cereal grains; maize (*Zea mays* L.) is the most important. During 1996-97, maize prices in Puerto Rico ranged from $11.75 to $14.25/hwt in comparison with $9.50 to 10.75/hwt in 1994-95 (FFAPR, 1996). Meanwhile, gross income from milk production declined from $195.2 million in 1994-95 to $189.9 million in 1995-96.

Forage sorghums produce abundant high-quality forage (Torres-Cardona et al., 1986; Sotomayor-Ríos et al., 1985a, 1989) of excellent feed value (Moyá-Guzmán, 1982). In many tropical areas, forage sorghums are in great demand because of their fast growth and high dry matter yield potential and as an alternative to perennial forages when the latter are in a low-biomass production period. All forage sorghums except the sudangrasses produce grain that adds to feeding quality and enhances utilization by animals. Currently grown in Puerto Rico are commercial forage sorghum hybrids which produce yields comparable to those of Millo Blanco (MB) (Sotomayor-Ríos et al., 1985b). However, seed of commercial forage sorghum hybrids is costly and cannot be reused by the farmer. Seed of MB as well as that of its F_1 hybrid can be produced locally. This production would reduce costs for island livestock producers. However, MB produces grain only during short days in Puerto Rico.

Millo Blanco is a native, robust, tall (one-dwarf), photoperiod-sensitive (PS) forage sorghum which has an excellent dry matter yield (DMY) (Sotomayor-Ríos et al., 1985a, 1989). MB plant is purple; its seeds are large, cream colored to white, and are covered with heavy glumes with long awns. The seeds of MB do not have a testa but rather a mesocarp. MB has dry stalks (white midrib) and strong adventitious roots. It is highly and moderately tolerant of toxic levels of manganese and aluminum, respectively, in the soil (Ritchey et al., 1991). Plant height and days to flower of MB vary according to its planting date. When planted in daylengths of less than 12 h, it flowers in about 61 days, attaining an appropriate plant height (PHt) of about 1 m. MB takes more than 240 days to flower and reaches a PHt of over 3 m when daylength is more than 12 h (Quiles-Belén et al., 1992). In 1990, an improved version of MB was released by the USDA; and in 1996 it was registered as germplasm (Sotomayor-Ríos et al., 1996). Lines capable of flowering throughout the year and retaining constant PHt have recently been developed from MB. These lines could be used as parents for the development of photoperiod-insensitive (PI) forage sorghum hybrids.

Greenleaf (GL) sudangrass was developed and released by the Texas Agricultural Experiment Station, College Station (Karper, 1955). It has sweet and juicy stalks, is leafy, tillers freely, and has high yields under favorable soil and moisture conditions. GL is resistant to leaf blight (*Helminthosporium turcicum* Pass) and also to several bacterial foliage diseases.

The objective of this study was to evaluate PHt, leaf area (LA), and forage yield and quality of MB, ATx623 × MB, GL, and ATx623 × GL when planted on the 15th day of each month for two years on an Oxisol in northwestern Puerto Rico. ATx623 × GL is a well-known commercial hybrid (PI), whereas ATx623 × MB (PS) has never been evaluated.

MATERIALS AND METHODS

The experiment was conducted in 1990 and 1991 at the USDA-ARS Isabela farm in northwestern P.R., 18°7' N, 67°W, at an elevation of 138 m. The soil at the farm is an Oxisol (Typic Hapludox) with a pH of approximately 5.5. Rainfall at Isabela follows a common pattern for the tropics with a marked dry season from December to March. However, moisture was not a limiting factor in this experiment; overhead irrigation was applied as needed.

The hybrids used were developed by the authors at the Tropical Agriculture Research Station (TARS). Cytoplasmic male-sterile line sorghum ATx623 was used as the female parent and MB and GL sudangrass as the male parents. The four genotypes (GL, MB, ATx623 × GL and ATx623 × MB) were planted the 15th day of each month from January to December for two consecutive years. Plantings were made with a two-row cone seeder equipped with a double-disk opener and packer wheel. Plots were 6 m long with five rows. Spacing between rows was 0.9 m, equivalent to a population density of about 130,000 plants per hectare. At planting and after each 60-d harvest interval, 15-5-10 fertilizer was applied to all plots at a rate of 560 kg/ha. Weeds were controlled by Milogard 80W[5] (propazine) [2-chloro-4,6-bis (isopropylamino)-s-triazine] applied at a rate of 2.5 kg ai/ha immediately after planting. During the two years, a total of forty-eight 60-d harvests were made. Plants in the three center rows of each plot were cut at about 20 cm from ground level and weighed. Harvests were used to determine leaf area, forage yield and dry matter content (DMC) and to provide samples for chemical analyses. Before each cutting, measurements were taken of plant height PHt (from the ground to the midpoint of the upper leaf blade) and of LA by using a portable meter (Model Ll-300, Lambda Instruments Corporation). In vitro dry matter digestibility (IVDMD) was determined by the two-stage technique of Tilley and Terry (1963).

The experimental design was a randomized complete block in a split-plot arrangement with four replications. Planting dates were the whole plots and genotypes were the sub-plots. It was analyzed as a mixed model with year and block (year) as random effects and genotypes as a fixed effect, using the mixed procedure in SAS version 6.11 for Windows (PC SAS) (SAS Institute, Inc., 1987).

RESULTS AND DISCUSSION

In the tropics, photoperiod-sensitive plants like sorghum require more than 60 and during seasons of long days more than 180 days to flower (Figure 1). The photoperiod sensitive MB and its F_1 hybrid flowered within 60 days when planted from October through January, months with daylengths less than 12 h. When planted from February through September (11.3 to12.1 h of light), they failed to flower within 60 days of growth and consequently remained at a vegetative stage, requiring more than 60 and up to 240 days to flower (Table 1).

Planting date × genotype interaction was significant for all traits except DMC and IVDMD (Table 2). The years were found to be non-significant; therefore, the ANOVAS were combined over the years. Except for IVDMD and DMC, there was a significant contrast for all traits between PI and PS and among parents and their hybrids (Table 2). Ta-

[5]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute an endorsement of equipment or materials by the USDA-ARS, nor is this mention a statement of preference over other equipment or material.

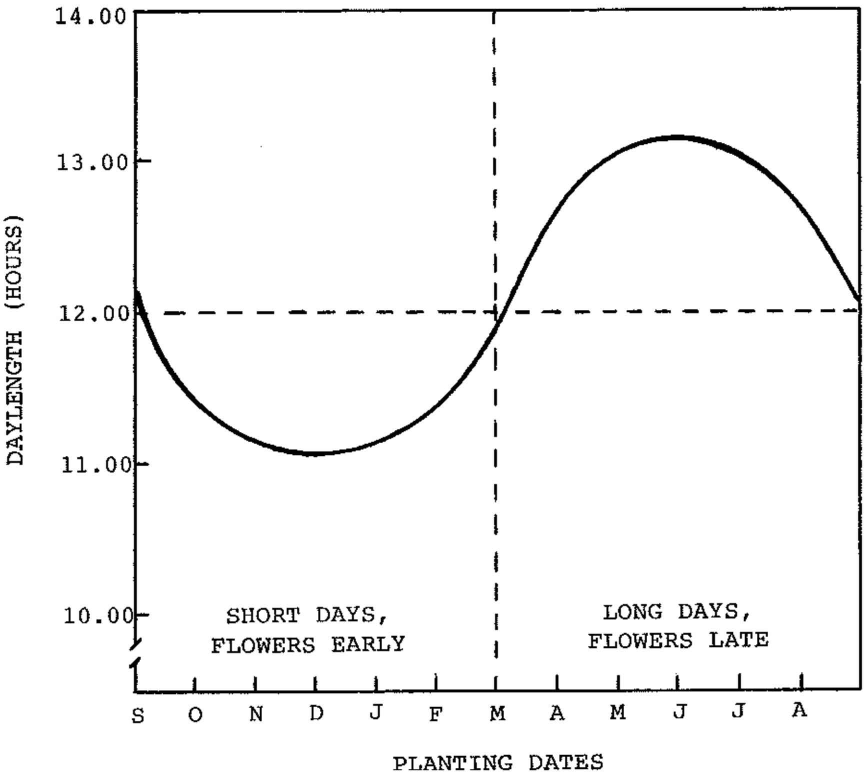

FIGURE 1. Effect of daylength on flowering of photoperiod-sensitive sorghums planted throughout the year in Puerto Rico.

ble 3 shows the mean PHt and LA of the four genotypes for each month of planting during the two-year period. The PS sorghums (MB and ATx623 × MB) were significantly taller (21%) than the PI genotypes. Plant height of the PS genotypes increased with increasing daylength up to the June 15 planting and then, except for the August 15 planting of the hybrid, decreased slightly up to the December 15 planting. Plant height and days to midflower were closely correlated with most of the tropical sorghum varieties that have been studied in Puerto Rico (Miller et al., 1968). Plant height of hybrid ATx623 × MB increased 36% from the January 15 to the June 15 planting, whereas the increase of MB for the same period was 41%. Hybrid ATx623 × MB had significantly taller plants in the June to September plantings. On the average, the ATx623 × MB was significantly taller than the other genotypes (Table 3). In this study, the mean LA of the PS genotypes was significantly greater than that of the PI genotypes (Table 3). Millo

TABLE 1.—*Mean daylength and flowering response of photoperiod-insensitive (PI) and photoperiod-sensitive (PS) forage sorghums grown in successive monthly plantings during 1991 and 1992 at Isabela, P. R.*

Month of planting	Mean day length (hours)	PI		PS	
		Greenleaf (GL)	ATx623 × GL	Millo Blanco (MB)	ATx623 × MB
January	11.1	+[1]	+	+	—
February	11.3	+	+	—[2]	—
March	11.0	+	+	—	—
April	12 3	+	+	—	—
May	12.6	+	+	—	—
June	13.1	+	+	—	—
July	13.0	+	+	—	—
August	12.4	+	+	—	—
September	12.1	+	+	—	—
October	11.4	+	+	+	+
November	11.2	+	+	+	+
December	11.0	+	+	+	+

[1]+ = Flowering in 60 days or less.
[2]— = Not flowering in 60 days.

Blanco had significantly higher LA when planted in June and August, whereas ATx623 × MB had significantly higher LA when planted in August. Plant height and LA are important yield components in sorghum. Torres-Cardona et al. (1986) found them to be positively correlated with DMY and IVDMD. The high correlation of PHt and LA with DMY makes these traits useful tools for sorghum improvement programs.

Table 4 shows the pooled mean CP and IVDMD of the four genotypes for each month of planting during the two-year period. There were significant differences in CP among genotypes in terms of planting date. All of the CP mean values were slightly above 11%. The means of the hybrids were significantly lower than those of the parents. The mean CP of GL was lowest when planted in February (10.65%) but not significantly different from five of the other monthly values during the year. The value of ATx623 × GL was significantly lower when it was planted in February and March. The lowest mean CP of MB was for the February plantings, but this was not significantly different from the June mean. The mean CP of ATx623 × MB was lowest for the February plantings and significantly different from that of all of the other months. The mean IVDMD of the four genotypes was about 56%. The significantly lowest IVDMD value for GL and its hybrid was obtained when planted in April. The lowest values for MB and its hybrid also re-

TABLE 2.—*Analysis of variance for plant height (PHt), leaf area (LA), dry matter content (DMC), crude protein (CP), CP yield (CPY), dry matter yield (DMY) and in vitro dry matter digestibility (IVDMD) of four sorghum genotypes grown in successive monthly plantings during 1991 and 1992 at Isabela, P. R.*

Source of variation	PHt	LA	DMC	CP	CPY	DMY	IVDMD
Genotype (G)	**	**	NS	NS	**	NS	NS
Planting date (PD)	**	**	**	**	**	**	**
PD × G	**	**	NS	**	**	**	NS
PS vs PI	**	**	NS	*	**	**	NS
H vs GL	**	**	NS	NS	**	**	NS
H vs MB	**	**	NS	NS	**	**	NS

* = Significant at the P = 0.05 probability level.
** = Significant at the P = 0.01 probability level.
NS = Non-significant at the P = 0.05 probability level.
PS = Photoperiod sensitive; PI = Photoperiod insensitive.
H = Hybrids; GL = Greenleaf; MB = Millo Blanco.

sulted from the April planting, but they were not significantly different from most of the other monthly means. IVDMD values in this study compare favorably with those obtained at Isabela and Mayagüez for eight forage sorghums (Torres-Cardona et al., 1986).

Table 5 shows the pooled mean DMY and CPY of the four genotypes for each month of planting for the two-year period. ATx623 × MB was the highest DM producer, followed by MB, ATx623 × GL, and GL. These values shown are equivalent to annual yields of 32, 29, 26 and 20 t/ha for the four genotypes and compare favorably with those of other high-yielding forage sorghums previously studied at Isabela (Torres-Cardona et al., 1986; Sotomayor-Ríos, et al., 1985a, 1989). Mean DMY of the PS genotypes was significantly higher (32%) than that of the PI genotypes. Mean DMY of MB ranged from 2.75 t/ha (December planting) to 7.14 t/ha (June planting) and that of ATx623 × MB from 3.22 t/ha (January planting) to 7.51 t/ha (June planting). The mean DMY of the PS genotypes planted during June was significantly higher (7.33 t/ha), and represents a 96% increase over the December planting (3.74 t/ha). This increase in DMY was accomplished without a reduction in CP. Mean DMY of GL ranged from 2.91 t/ha (March planting) to 3.66 t/ha (August planting) and that of ATx623 × GL from 3.80 t/ha (February planting) to 4.73 t/ha (January planting). As expected, the DMY of the PI genotypes was not affected by planting date.

ATx623 × GL was capable of producing 33% more DMY per hectare than its male parent, GL sudangrass, while ATx623 × MB produced 11% more than MB and 22% more than ATx623 × GL (Table 5). At a

TABLE 3.—*Mean plant height and mean leaf area of greenleaf sudangrass (GL), ATx623 × GL, Millo Blanco (MB), and ATx623 × MB planted the 15th day of each month during 1991 and 1992, Isabela, P.R.*

Month of planting	Plant height				Leaf area			
	GL	ATx623 × GL	MB	ATx623 × MB	GL	ATx623 × GL	MB	ATx623 × MB
	m				cm^2			
January	1.91 cd[1]	2.32 g	2.18 e	2.42 e	4619 e	5569 de	5321 c	6020 f
February	1.98 bc	2.46 d-g	2.64 c	3.00 c	4912 cd	5644 c-e	5699 d	6349 e
March	2.18 a	2.53 b-f	2.69 c	2.99 c	4443 ef	5861 ab	6205 cd	6709 c
April	2.14 a	2.77 a	2.63 c	3.00 c	4845 d	5802 a-c	6399 b	6653 cd
May	2.18 a	2.49 c-f	2.31 de	2.82 d	4312 f	5607 de	5798 d	6518 de
June	2.12 ab	2.66 ab	3.08 a	3.30 ab	5245 ab	5922 a	6622 a	6894 b
July	2.22 a	2.62 bc	3.07 a	3.24 ab	5130 b	5736 b-d	6284 b	6802 bc
August	2.13 a	2.57 b-e	3.19 a	3.33 a	5373 a	5651 c-e	6621 a	7135 a
September	2.10 ab	2.60 b-d	2.85 b	3.16 b	5412 a	5611 de	6046 c	6797 bc
October	1.89 cd	2.57 b-e	2.63 c	2.93 cd	5087 bc	5582 de	6039 c	6642 cd
November	1.91 cd	2.40 fg	2.34 d	2.52 e	4881 d	5520 e	5390 e	6059 f
December	1.83 d	2.45 e-g	2.21 de	2.43 e	4883 d	5565 de	5181 e	6036 f
$\bar{x}$	2.05 c[2]	2.54 b	2.65 b	2.93 a	4929 c	5673 b	5967 b	6551 a

[1]Values in columns followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.
[2]Overall means in rows followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.

TABLE 4.—*Mean crude protein and mean in vitro dry matter digestibility of greenleaf sudangrass (GL), ATx623 × GL, Millo Blanco (MB), and ATx623 × MB planted the 15th day of each month during 1991 and 1992, Isabela, P.R.*

Month of planting	Crude protein				In vitro dry matter digestibility			
	GL	ATx623 × GL	MB	ATx623 × MB	GL	ATx623 × GL	MB	ATx623 × MB
	%				%			
January	11.69 a[1]	11.05 a	11.26 ab	11.76 a	55.9 ab	56.5 a	56.7 a-c	56.4 ab
February	10.65 c	10.41 b	10.60 c	10.26 d	54.9 b	56.1 a	54.9 cd	54.9 bc
March	11.13 bc	10.35 b	11.19 ab	10.76 c	54.9 b	57.0 a	57.4 ab	58.0 a
April	11.76 a	11.18 a	11.53 a	10.98 bc	52.4 c	52.5 b	54.1 d	53.6 c
May	11.44 ab	11.00 a	11.13 ab	11.02 bc	58.0 a	57.5 a	57.7 a	57.7 a
June	11.02 bc	11.29 a	11.01 bc	11.19 bc	56.1 ab	56.7 a	57.3 a-c	56.8 ab
July	11.08 bc	11.32 a	11.26 ab	11.20 bc	56.1 ab	56.0 a	55.0 b-d	55.2 bc
August	11.28 ab	11.34 a	11.17 ab	11.25 bc	56.3 ab	55.4 a	56.0 a-d	55.9 a-c
September	11.37 ab	11.28 a	11.16 ab	11.08 bc	55.6 ab	55.3 a	55.5 b-d	55.8 a-c
October	11.14 bc	11.37 a	11.26 ab	11.22 bc	56.7 ab	55.4 a	56.0 a-d	55.9 a-c
November	11.01 bc	11.19 a	11.39 ab	11.35 ab	55.3 b	57.0 a	56.2 a-d	56.5 ab
December	11.15 b	11.27 a	11.47 ab	11.35 ab	56.1 ab	56.0 a	55.3 b-d	56.7 ab
$\bar{x}$	11.23 a[2]	11.09 b	11.20 a	11.04 b	55.7 a	56.0 a	56.0 a	56.1 a

[1]Values in columns followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.
[2]Overall means in rows followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.

TABLE 5.—*Mean dry matter yield and mean crude protein yield of greenleaf sudangrass (GL), ATx623 × GL, Millo Blanco (MB), and ATx623 × GL planted the 15th day of each month during 1991 and 1992, Isabela, P.R.*

Month of planting	Dry matter yield				Crude protein yield			
	GL	ATx623 × GL	MB	ATx623 × MB	GL	ATx623 × GL	MB	ATx623 × MB
	t/ha				t/ha			
January	3.22 b-e[1]	4.73 a	2.94 g	3.22 g	0.38 a-c	0.53 ab	0.33 g	0.38 d
February	2.92 de	3.80 f	4.60 f	5.54 de	0.29 e	0.39 g	0.47 f	0.58 c
March	2.91 e	4.57 a-d	4.47 f	5.12 f	0.30 de	0.46 d-f	0.49 ef	0.57 c
April	3.55 ab	4.08 ef	5.55 d	5.80 d	0.39 ab	0.45 ef	0.64 c	0.67 b
May	3.19 c-e	4.12 ef	4.80 f	5.00 f	0.34 cd	0.44 f	0.53 de	0.57 c
June	3.40 a-c	4.37 b-e	7.14 a	7.51 a	0.39 ab	0.48 c-f	0.78 a	0.83 a
July	3.15 c-e	4.54 a-d	5.96 c	6.60 c	0.35 bc	0.51 a-c	0.65 b	0.82 a
August	3.66 a	4.66 ab	6.38 b	6.95 b	0.41 a	0.54 a	0.68 b	0.71 b
September	3.36 a-c	4.60 a-c	5.18 e	6.27 c	0.37 a-c	0.51 a-c	0.55 d	0.69 b
October	3.41 a-c	4.38 b-e	4.67 f	5.22 ef	0.37 a-c	0.48 c-f	0.49 ef	0.56 c
November	3.27 b-d	4.22 de	2.99 g	3.39 g	0.36 a-c	0.46 d-f	0.34 g	0.37 d
December	3.20 b-e	4.28 c-e	2.75 g	3.36 g	0.36 a-c	0.48 c-f	0.33 g	0.37 d
x̄	3.27 d[2]	4.36 c	4.79 b	5.33 a	0.36 c	0.48 b	0.53 a	0.59 a

[1]Values in columns followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.
[2]Overall means in rows followed by a common letter do not differ significantly at P = 0.01 according to Duncan's multiple range test.

58-d cutting interval, a DMY of 7.7 t/ha was reported for a cross of CK-60 × MB (Sotomayor-Ríos and Telek, 1977). The DMY of that hybrid was 27% higher than the value of MB in the present study.

ATx623 × MB was the highest CPY producer, followed by MB, ATx623 × GL, and GL, with means of 0.59, 0.53, 0.48, and 0.36 t/ha, respectively. The CPY of the PS genotypes was 33% higher than that of the PI group. The overall mean CPY was superior to that reported for previous plantings of forage sorghums at Isabela (Torres-Cardona, et al., 1986). Significantly higher CPY was obtained when the genotypes were planted during long rather than short days (Table 5). Millo Blanco and its hybrid had significantly higher CPY when planted June 15 than when planted the rest of the year. This higher CPY was the result of higher DMY rather than an increase in CP (Table 5).

This study demonstrated the superiority of the PS over the PI genotypes and of the hybrids over their parents for all traits except IVDMD and DMC (Tables 3 to 5). Future research should concentrate on the development of cytoplasmic male-sterile MB lines for use as female parents with selected forage sorghum parents in the development of superior hybrids.

The forage sorghum genotypes evaluated in this study gave excellent yields and could all be utilized as a temporary feed source for lactating dairy cows and other high quality livestock if supplemented with high-protein legume forages (e.g., *Arachis* and *Stylosanthes* spp.) and/or grain concentrates. Millo Blanco lines capable of producing abundant forage and grain throughout the year (PI) are being developed at TARS. These lines, in hybrid combinations, could provide an alternative to more expensive corn-based concentrate feed for livestock production in Puerto Rico and thus help to cut costs and stimulate an increasing milk production.

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