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RESPONSE OF FORAGE SORGHUM TO TWELVE PLANTING DATES IN PUERTO RICO

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ABSTRACT

Cytoplasmic male-sterile sorghum ATx623 (*Sorghum bicolor* (L.) Moench) was crossed with male parents Millo Blaco (MB) (photoperiod sensitive), and Greehleaf (GL) (photoperiod insensitive). The genotypes were planted on the 15th day of each month during 1984 and harvested at 60 day intervals, Dry forage yield (DFY), crude protein yield (CPY), leaf area (LA), plant height (PHt), rust incidence (R) and *in vitro* dry matter digestibility (IVDMD) were calculated for each cutting. Analysis of variance showed significant differences among genotypes (G) and planting dates (PD) x G interaction for all traits except dry matter content (DMC) and IVDMD. All traits showed significant differences among PD. ATx623 x GL had nearly constant production (3–4 tonnes ha^{-1} harvest^{-1}). ATx623 x MB fluctuated from appoximately 3 tonnes ha^{-1} per harvest from December to January plantings to 7.68 tonnes ha^{-1} harvest^{-1} at the June planting. Genotypes showed similar IVDMD at all harvests. During long day plantings photoperiod sensitive sorghums showed less R than the insensitive types. The excellent DFY, CPY and IVDMD, and low R incidence of photoperiod sensitive genotypes during long days make them valuable materials for intensively managed tropical sorghum. ATx623 and MB proved outstanding for developing superior F_1 forage sorghum hybrids in Puerto Rico.

RESUMEN

Sorgo fitoplásmico estaminado y esteril ATx623 (*Sorghum bicolor* (L.) Moench), fue cruzado con parentescos estaminados, – Millo Blanco (MB), (sensitivo a la luz) y Grennleaf (GL), (insensitivo a la luz) –. Los genotipos fueron plantados el quince de cada mes, durante el año 1984 y cosechados cada sesenta dias. El rendimiento de forraje en seco (DPY), rendimiento de proteina en bruto (CPY), superficie de la hoja (LA), altura de la planta (PHt), incidencia de la Roya (R) y la digestibilidad de materia seca *in vitro* (IVDMD), fueron calculados para cada cosecha. Un análisis de la variables mostrarón una diferencia significativa, de los genotipos (G) y de las fechas de siembra (PD) x interacción en todos los puntos mencionados anteriormente, excepto el conteniod G, de materia seca (DMC) y el IVMD. Todos los rasgos mostraron diferencias significativas entre las PD. AT623 x GL casi tuvieron una producción constante (3–4 ton/ha/cosecha). AT x 623 x MB fluctuarón de aproximademente 3 ton/ha/cosecha en siembras de Diciembre a Enero, a 7.68/ton/ha/cosecha en la siembra de Junio. Los genotipos mostraron un IVDMD durante todas las cosechas. Durante las siembras de tipo de dia largo, el sorgo sensitivo a la luz mostró una incidencia menor al ataque de la Roya que, el de aquellos del tipo insensitivo. Los excelentes DPY, CPY y IVDMD y la baja incidencia al ataque de la Roya de los genotipos sensitivos a la luz durante los dias largos, hacen de ellos un material de valor para las praderas de sorgo tropical, manejadas intensivamente. AT x 623 y MB mostraron ser sobresalientes para desarrollar un sorgo de forraje híbrido F1, en Puerto Rico.

Keywords: Forge sorghum, Photoperiodism, Puerto Rico

Garner and Allard (1923), coined the term photoperiodism to define plant response to daylength. Later studies demonstrated that the nyctoperiod (length of night), rather than length of day, was actually the operative factor in control of plant responses (Gardner *et al*, 1985). According to Miller *et al.* (1968) the response of tropical varieties to photoperiod has prevented universal use of much of the germplasm which exists in many short-day species, including sorghum (*S. bicolor* L. Moench). Studies by Quinby (1967) have shown that sorghum varieties differ in maturity because they respond differently to photoperiod and temperature. According to these authors differences in the temperate zone sorghums are apparently controlled by four gene loci with an allelic series at each locus. In plantings made for 12 consecutive months in 1964 and 1965 at Mayaguez, Puerto Rico by Miller *et al.* (1968) the effects of daylength on number of days to anthesis and plant height were observed in 15 tropical sorghums and compared with seven U.S. sorghums and a set of eight maturity genotype testers. These authors were able to bring all types into flower at about the same time in the said location by planting from mid-September through mid-November when daylength was below the critical level for these varieties. The U.S. sorghums were unaffected by changes in the photoperiod, whereas significant correlations were observed between days from planting to anthesis and plant height in most of the tropical sorghums.

The effect of planting dates and consequently the influence of photoperiodism on the yield and agronomic characters of tropical sorghums has not been studied in Puerto Rico. On the other hand, the photoperiodic effects on crops such as *Tephrosia vogelii, Pennisetum typhoides, Zea mays* and other short-day tropical species have received considerable attention (Barnes and Burton, 1966; Irvine and Freyre, 1966; Mc Clelland, 1928).

The objectives of this study were: (1) to determine the influence of photoperiod on plant height, leaf area and dry forage yield of photoperiod sensitive and photoperiod insensitive forage sorghums, and (2) to establish planting dates for optimizing yield and nutrient content of forage sorghums in Puerto Rico.

Materials and methods

The experiment was conducted at the experiment farm of the Tropical Agriculture Research Station (TARS), USDA, ARS, S & E, at Isabela, Puerto Rico, approximately 18° N latitude. Environmental conditions were relatively uniform throughout the year (Table 1). Daylength varies from 13.13 to 11.02

Table 1. Mean monthly daylengths, mean monthly maximum rainfall, and mean monthly maximum temperature at Isabela, Puerto Rico in 1984.

Month	Mean day length (hours *)	Mean rainfall (cm)	Mean temperature (°C)
January	11.11	2.41	23.3
February	11.30	14.94	22.2
March	11.02	2.97	23.8
April	12.32	1.68	25.2
May	12.59	13.56	25.3
June	13.12	18.19	25.9
July	13.07	7.52	25.6
August	12.43	20.50	26.2
September	12.14	26.70	25.7
October	11.44	37.36	25.3
November	11.17	7.19	21.6
December	11.04	0.80	22.3

* Longest day 13.13 (June 21), shortest day 11.02 (December 20); 12-hour days occur March 13 and September 29.

hours. Mean monthly temperatures varied from 21.6 to 26.2° C. The soil at the Isabela location is an Oxisol (Tropeptic Haplorthox). Rainfall follows a common pattern for the tropics with a marked dry season from December to March and an over-all monthly average of 136.5mm. Moisture was not a limiting factor, however, since irrigation was applied as needed.

The four genotypes were: Millo Blanco (MB), a local forage sorghum; hybrid ATx623 x MB (photoperiod sensitive); Greenleaf (GL) a sudangrass; and ATx623 x GL (photoperiod insensitive). Female parent ATx623 is a cytoplasmic male-sterile commonly utilized for grain and forage hybrid production.

Plantings of the four sorghums were made on the 15th day of each month starting in January during 1984. The experimental design was a randomized complete block with four replications. For weed control propazine [2-chloro-4, 6-bis (isopropylamino) -s-triazine] was applied at a rate of 2.5 kg of active ingredient ha^{-1} immediately after planting. At planting, and after each 60-day cutting interval a 15:5:10 fertilizer was applied to all plots at a rate of 560 kg ha^{-1}. Before each cutting, measurements were made of plant height (from the ground to the midpoint of the upper leaf blade) and leaf area (by a portable area meter-Model LI-300 Lamba Instruments Corporation). Yields of green forage (GFY), dry forage (DFY) and crude protein (CPY) were calculated for each cutting. Samples were analyzed for dry matter content (DMC) and crude protein content (CPC) at TARS and *in vitro* dry matter digestibility (IVDMD) was determined at the University of Georgia based on the Tilley and Terry (1963) two-stage technique. Analyses of variance and regression techniques were utilized in interpretation of the data, according to Snedecor and Cochran (1967).

Results and discussion

Miller *et al.* (1968) found that individual varieties of sorghum have different critical photoperiods which inhibit floral development. In this study the flowering of Millo Blanco and its hybrid was delayed when planting was from February through September (11.3 – 12.1 hours of light). On the other hand, Greenleaf sudangrass and its hybrid flowered throughout the year, although earlier during long days (Table 2). The advantage of utilizing photoperiod sensitive forage sorghums is that they remain vegetative during the season of long days, thus maintaining a forage of high quality. It is essential to test and compare photoperiod sensitive and insensitive sorghums to determine how each can best be utilized to optimize forage production and quality in the tropics.

The combined analysis of variance showed that planting dates (PD) had F values that were significant for all traits. Significant differences were also observed among genotypes (G) and G x PD interaction for DFY, CPY, CPC, PHt, LA and R (Table 3).

Photoperiod sensitive sorghums require over 60 and in some instances 120 or 180 days to flower in the tropics during seasons of long days. This effect is clearly illustrated for Puerto Rico in Fig. 1. Previous studies by the authors have demonstrated a consistent relationship of leaf area (LA) with sorghum forage yields. In this study LA increased with increasing daylength up to the 15 June planting in the photoperiod sensitive sorghums, then decreased steadily through the 15 December planting. A comparison of planting dates during the short-day period (15 January) versus the long-day period (15 June), showed a 29 per cent and 27 per cent increase in LA in the sensitive and insensitive male parents, respectively (Fig. 2). Miller *et al.* (1968) showed that PHt and days to flower were closely correlated in nearly all of 11 sorghum varieties. Hybrid Millo Blanco PHt increased 33 per cent from the 15 January to the 15 June planting, while the corresponding increase for Milo Blanco male parent was significantly higher (60 per cent) (Fig. 3). Greenleaf sundangrass and its hybrid PHt increased 19 and 5 per cent from 15 January to 15 July and from 15 January to 15 August plantings, respectively. The photoperiod sensitive forage sorghums Millo Blanco hybrid and its male parent responded to planting at the time of longest days (15 June) with increases of 143 and 104 per

Table 2. Flowering responses of photoperiod insensitive and photoperiod-sensitive forage sorghums grown in successive monthly plantings at Isabela, Puerto Rico, in 1984.

	Photoperiod-insenstitive sorghum		Photoperiod sensitive sorghum	
Month	Greenleaf (GL)	ATx623xGL	Millo Blanco (MB)	ATx623xMB
January	+ [1]	+	+	+
February	+	+	- [2]	-
March	+	+	-	-
April	+	+	-	-
May	+	+	-	-
June	+	+	-	-
July	+	+	-	-
August	+	+	-	-
September	+	+	-	-
October	+	+	+	+
November	+	+	+	+
December	+	+	+	+

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

Table 3. F values for the combined analysis of variance of dry forage (DFY) and crude protein (CPY) yields, day matter (DMC) and crude protein (CPC) contents, plant height (PHt), leaf area (LA), *in vitro* dry matter digestibility (IVDMD) and rust (R) incidence in forage sorghums grown at Isabela, Puerto Rico.

Source of variation	DF	DFY	CPY	DMC	CPC	Ht	LA	IVDMD	R
Planting Date (PD)	11	110.08**	93.71**	9.32**	17.59**	91.64**	68.72**	7.46**	11.38**
Replications (R)	36	0.09^{NS}	1.35^{NS}	0.49^{NS}	1.64*	1.20^{NS}	0.81^{NS}	1.29^{NS}	1.25^{NS}
Genotypes (G)	3	252.30**	233.58**	0.54^{NS}	4.18**	841.41**	713.25**	1.63^{NS}	76.08*
PDxG	33	22.53*	18.47**	0.93^{88}	4.54**	18.61**	9.03**	1.18^{NS}	6.43**
Contrasts									
Greenleaf (GL) vs Millo Blanco (MB)	1	344.65**	289.14**	0.66^{NS}	0.12^{NS}	114.77**	761.96**	2.63^{NS}	4.06*
Hybrid (H)	1	406.60**	411.4**	0.28^{NS}	7.64**	1303.41**	1377.53**	1.05^{NS}	223.48*
(GL vs MB) H	1	5.65*	0.14^{NS}	0.66^{NS}	4.80*	106.05**	0.28^{NS}	1.20^{NS}	0.71^{NS}

* Significant at the 0.05 probability level
** Significant at the 0.01 probability level.

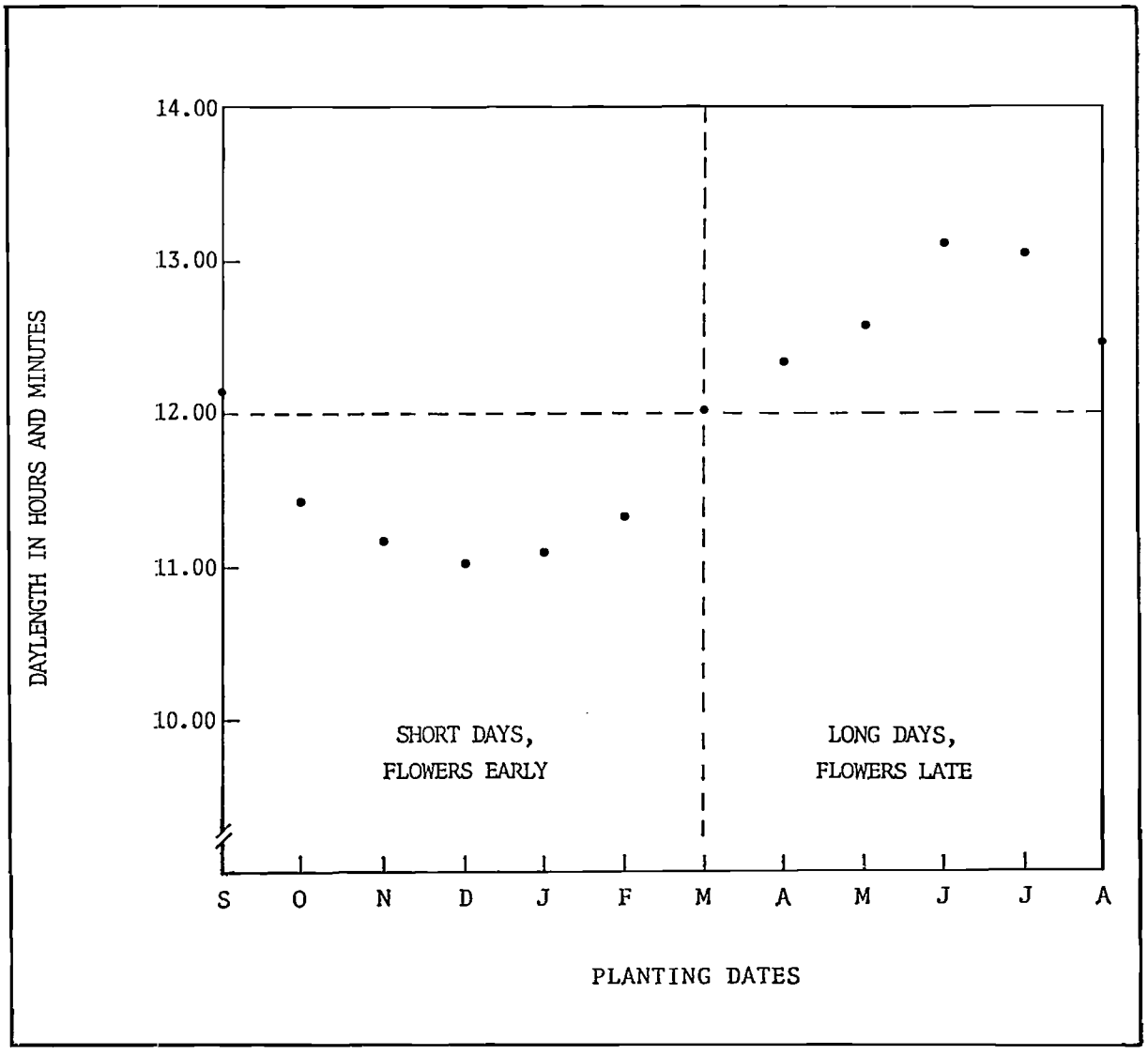

Figure 1 Relationship between planting dates and daylength of sorghum in Puerto Rico.

cent in DFY, respectively, compared with the 15 January planting (Fig. 4). However, in the case of Greenleaf sudangrass hybrid and its male parent the same comparison showed increases of only 1 and 15 per cent respectively.

The *in vitro* dry matter digestibility (IVDMD) was affected by PD although no clean cut differences among genotypes were observed in this criterion. The IVDMD per cent ranged from 51.2 to 59.7 and from 51.6 to 61.6 in the photoperiod insensitive and photoperiod sensitive sorghums, respectively (Table 4).

Differences among PD for DFY were dramatically demonstrated in photoperiod sensitive forage genotypes in 12 monthly plantings. A significant effect of less magnitude was found in photoperiod insensitive genotypes.

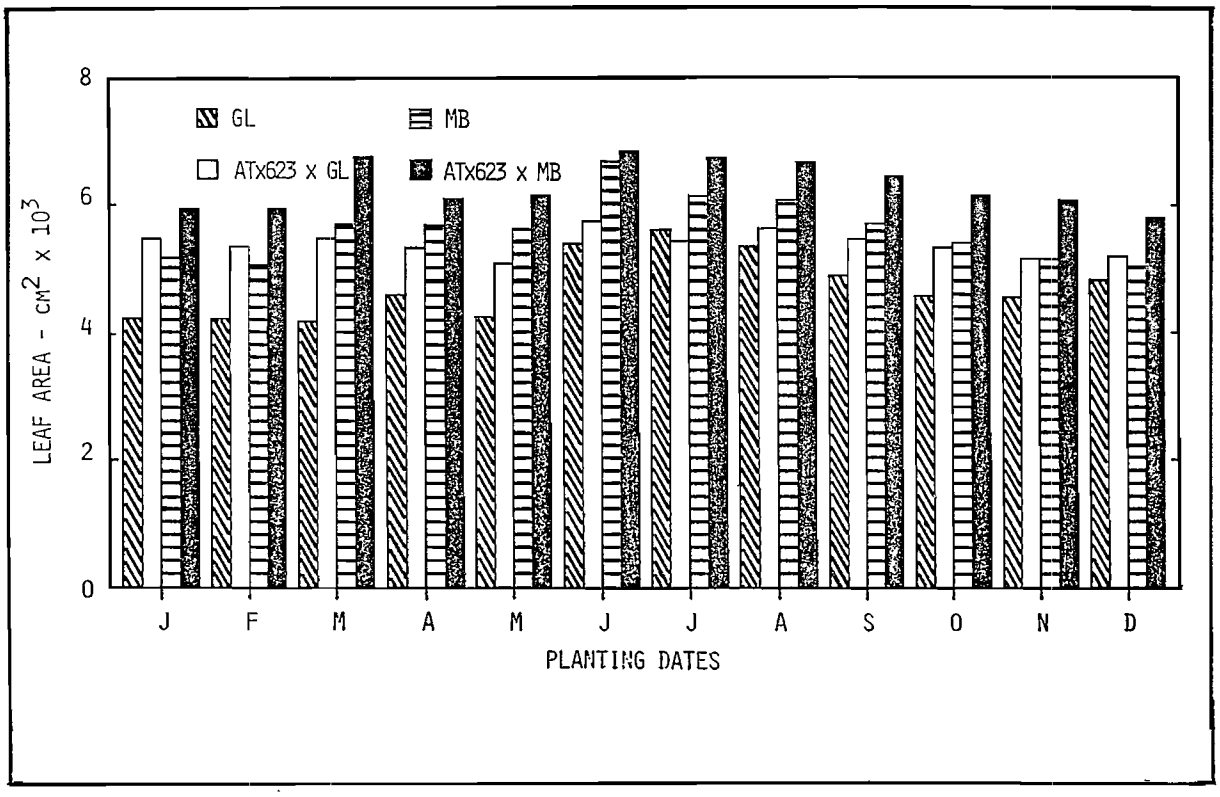

Figure 2 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in leaf area, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

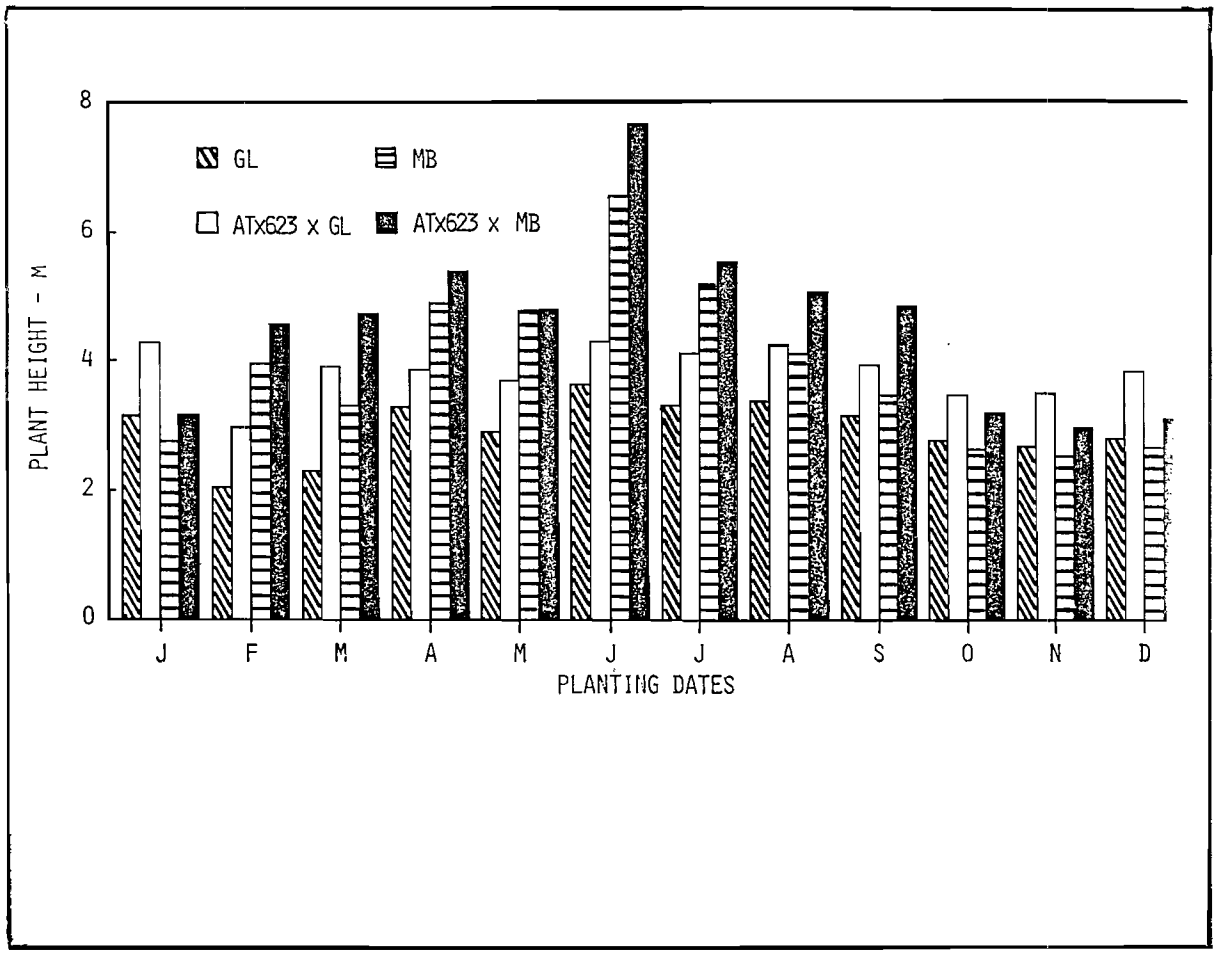

Figure 3 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in plant height, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

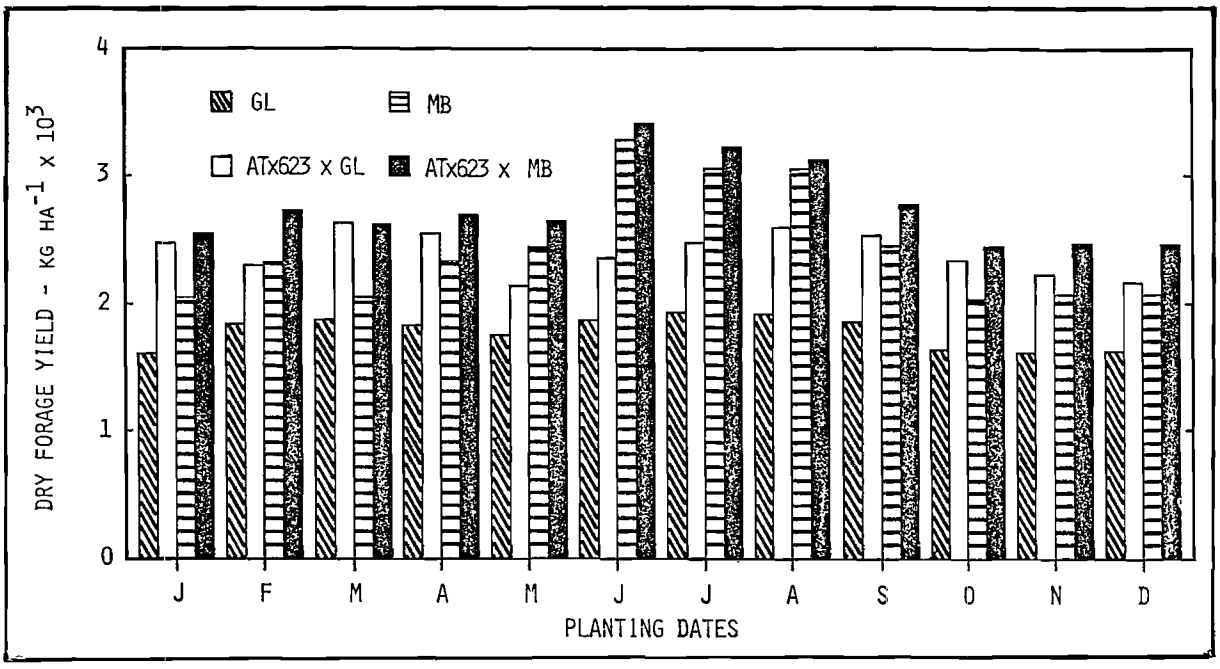

Figure 4 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in dry forage yield, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

Table 4. Mean *in vitro* dry matter digestibility of photoperiod-insensitive and photoperiod-sensitive forage sorghums grown in successive monthly plantings at Isabela, Puerto Rico, in 1984.

	Photoperiod-insenstitive sorghum		Photoperiod sensitive sorghum	
Month	Greenleaf (GL)	ATx623xGL	Millo Blanco (MB)	ATx623xMB
January	55.8	57.9	58.8	56.8
February	51.2	56.9	53.6	51.6
March	59.7	59.7	61.6	60.7
April	54.4	52.5	57.3	54.8
May	59.2	56.5	60.7	56.5
June	57.7	56.7	57.5	57.9
July	56.0	57.0	57.4	54.3
August	58.1	56.3	54.8	56.2
September	55.3	54.6	57.0	55.9
October	56.1	54.3	55.9	56.0
November	55.7	55.4	57.4	57.1
December	57.0	56.1	54.9	55.8
X	56.4	56.2	57.2	56.1

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