

# Yield and agronomic evaluation of ten sorghum hybrids on the south coast of Puerto Rico in 1993 and 1994<sup>1,2</sup>

Jeffery A. Dahlberg<sup>3</sup> and Pablo Madera-Torres<sup>4</sup>

## ABSTRACT

Annually, Puerto Rico imports close to 220,000 t of feed grain from the United States and other countries at a cost of \$16.0 million, for use as livestock and chicken feed. Previous studies have shown that sorghum [*Sorghum bicolor* (L.) Moench] can be successfully grown in areas of the southern coast of Puerto Rico, all of which means an alternate crop and a way to reduce grain imports. Grain yield potentials of 10 hybrids of sorghum, including seven red and three white-seeded types, were evaluated at Juana Díaz on the south coast of the island. The test was planted 5 May 1993 and 23 May 1994 following a split-plot experimental design with three replications. Three rows were planted per plot. The middle row was used for yield and other agronomic trait evaluations. Mean grain yields of the test were 5,020 kg/ha. Top-yielding Cargill Ma Cau 90 (6,240 kg/ha) significantly exceeded yields of all other hybrids except DK-65. Mean values of other agronomic characteristics were days to anthesis, 63.9; plant height, 150.4 cm; 100-seed weight, 3.44 g; harvest index, 31%. Only plant height was significantly and positively correlated with grain yield ( $r = 0.34$ ). These high yield potentials have implications for lessening Puerto Rico's heavy dependence on imported feed grains.

Key words: sorghum, hybrids, yield, feed, import

## RESUMEN

Evaluación agronómica de diez híbridos de sorgo en la costa sur de Puerto Rico en 1993 y 1994

Estudios previos han demostrado que el sorgo [*Sorghum bicolor* (L.) Moench] se puede cultivar a escala comercial con éxito en áreas de la costa sur de Puerto Rico. Esto significa que puede ser un cultivo alternativo y una manera de reducir la importación de grano para concentrado, que sobrepasa las 200,000 toneladas anuales, provenientes de los Estados Unidos y otros países con un valor de \$16.0 millones. Se determinó el potencial de rendimiento y comportamiento agronómico de 10 híbridos de sorgo (siete de grano rojo y tres de grano blanco) en la subestación Experimental Agrícola de Fortuna, municipalidad de Juana Díaz. El experimento se sembró el 5 de mayo de 1993 y 23 de mayo de 1994 utilizando un diseño de bloques al azar con parcelas divididas con tres repeticiones. La parcela experimental

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<sup>3</sup>Research Geneticist, Agricultural Research Service, Tropical Agriculture Research Station, P.O. Box 70, Mayagüez, PR 00681.

<sup>4</sup>Agronomist, Agricultural Research Service, Tropical Agriculture Research Station.

consistió de tres hileras donde la hilera central se utilizó para obtener datos de rendimiento y de otras características. En promedio los 10 híbridos produjeron 5,020 kg/ha. El híbrido de mayor rendimiento fue el Cargill Ma Cau 90 con una producción de 6,240 kg/ha, significativamente mayor que la de los demás híbridos, excepto DK-65. El híbrido Cargill Appolo fue el de menor rendimiento. Los valores promedio para otros caracteres agronómicos fueron días a mitad de florecida, 63.9 días; altura de la planta, 150.4 cm; peso de 100 semillas, 3.44 g; índice de cosecha, 31%. Además, se encontró una correlación significativa ( $r = 0.34$ ) entre altura de la planta y rendimiento de grano. El rendimiento demuestra que algunos de estos híbridos tienen potencial para ser sembrados a escala comercial y ayudar a reducir la dependencia de Puerto Rico en la importación de granos para concentrado de animales.

### INTRODUCTION

In 1994, sorghum [*Sorghum bicolor* (L.) Moench] ranked fifth among the most important cereal crops of the world after wheat (*Triticum* sp.), rice (*Oryza sativa* L., *Oryza glaberrima*), maize (*Zea mays* L.), and barley (*Hordeum vulgare*) in both total area planted and production. Eighty percent of the area devoted to sorghum is located within Africa and Asia, where average yields were 810 and 1,150 kg/ha, respectively (Food and Agriculture Organization of the United Nations, 1994). In 1992, sorghum was planted on approximately 5.4 million ha in the United States with an average yield of 4,566 kg/ha and a farm value of over \$1.7 billion (USDA, 1993).

In the United States, sorghum grain is used primarily for livestock feed and the vegetative parts for green chop, hay, silage, and pasture (Doggett, 1988; House, 1985). In 1989-90, the gross agricultural income of Puerto Rico was \$744.5 million with animal production accounting for 58% (\$435.4 million) of the total income earned. Milk and poultry contributed \$201.7 and \$85.2 million, while cereal and legume grains accounted for only \$3.4 million (Alamo, 1992). In 1987, Puerto Rico imported 193,220 t of yellow corn from the United States and other countries for livestock feed at a cost of \$15.9 million. Grain sorghum importation for animal feed was valued at \$260,768 (U.S. Dept. of Commerce, 1992).

Sorghum research on various management and control aspects has been done in Puerto Rico for over 30 years. Research areas covered have included fertilization (Sotomayor-Ríos and Lugo-López, 1978), weed control (Almodóvar-Vega, 1984; Miller et al., 1969), bird resistance (Sotomayor-Ríos, 1977), plant pathogen resistance (Bee-Rodríguez and Ayala, 1977; Feliciano et al., 1986; Hepperly, 1988), soil stress (Abruña et al., 1983; Wahab et al., 1976), sweet sorghum potential (Alsina et al., 1975), and forage quality and performance (Caro-Costas, 1981; Méndez-Cruz et al., 1990; Sotomayor-Ríos and Santiago,

1981). Few experiments, however, have dealt with commercial sorghum hybrid yield potential in Puerto Rico. Fox et al. (1974) reported a maximum yield of 4.3 t/ha for the cultivar RS671 grown on Ultisol and Oxisol soils. Wahab et al. (1976) reported a grain yield of 2,600 kg/ha for RS671 grown on Oxisol and Ultisol soils in Barranquitas and Corozal. Sotomayor-Ríos and Miller (1977) evaluated ten grain sorghum lines from the USDA/TAES Sorghum Conversion Program (Stephens et al., 1967). Mean yield was 2,212 kg/ha, with a yield range of 4,153 (IS 12666) to 910 (IS 12526C) kg/ha. Sotomayor-Ríos and Weibel (1978) developed hybrids from seven grain sorghums from the Sorghum Conversion Program and three cytoplasmic male-sterile lines for evaluation of yield and agronomic characteristics. Grain yield ranged from 4,261 to 1,866 kg/ha. Sotomayor-Ríos and Torres-Cardona (1984) evaluated the performance of 15 grain hybrids, comparing first and ratoon crops at two locations in Puerto Rico, Lajas and Isabela. The hybrid ATx623\*76SC490 produced yields of 6,463 and 4,429 kg/ha for the first and ratoon crops at Lajas, while ATx623\*RTam428 yielded 6,272 and 4,306 kg/ha at Isabela. The objective of this present study was to describe the yield potential of 10 commercially available grain sorghum hybrids for use in Puerto Rico.

#### MATERIALS AND METHODS

Ten grain sorghum hybrids (Table 1) were planted at the Fortuna Substation Farm, Agricultural Experiment Station (AES) of the University of Puerto Rico (UPR), in Juana Díaz. Mean maximum and minimum temperatures during the 1993 and 1994 growing season were 31.8° and 22.9° C and 32.6° and 22.8° C, respectively. Average monthly rainfall was 148.1 and 50.0 mm for 1993 and 1994, respectively, and the soil series is a San Antón (Cumulic Haplustolls).

The trials were planted on 5 May 1993 and 23 May 1994. The experimental design was a randomized complete block in a split-plot arrangement with three replications. Years were main plots; hybrids the sub-plots. Three rows were planted per plot. The middle row was used for the determination of yield and other agronomic characteristics. Rows were 6.1 m in length and spaced 0.91 m apart. After emergence, the hybrids were thinned to 110,000 plants per hectare. Weeds were controlled with a pre-emergence application of propazine [2-chloro-4,6-bis(iso-propyl-amino)-s-triazine] at the rate of 0.18 kg ai/ha, with an over-the-top spray of alachlor [2-chloro-2'-6'-diethyl-N-(methoxymethyl)acetanilide] at 227 g ai/ha at the five-leaf stage of growth, and a directed spray of alachlor at 227 g ai/ha and paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride) at 85.1 g ai/ha at the boot

TABLE 1.—Company name and description of plant and seed color of ten sorghum hybrids evaluated at the Fortuna Substation Farm, Juana Diaz, during 1993 and 1994.

Company	Hybrid	Plant color	Seed color
DeKalb-Pfizer Genetics	DK-64	Purple	Red
	DK-65	Red	Red
	DK-73	Reddish/Purple	Red
	DK-77	Tan	White
Pioneer Hi-Bred Int'l	Pioneer 8200	Purple	Red
	Pioneer 8240	Tan	White
Cargill Seed Co.	Cargill Ma Cau 90	Red	Red
	Cargill Marte 85	Purple	Red
	Cargill Apollo	Purple	White
	Cargill Jupiter	Purple	Red

stage. Insects were controlled with *Bacillus thuringiensis* var. *kurstaki* and methomyl [S-methyl N-[(methyl-carbamoyl)oxy]thioacetimidate] as needed. A preplant application of 15-5-10 fertilizer, with minor elements was incorporated into the soil at a rate of 560 kg/ha. Thirty days after planting, a 400 kg/ha application of ammonium sulfate was incorporated into the soil. Plots were sprinkler irrigated to minimize stress throughout the period of study.

Plots were harvested and grain yield data collected on 24 August 1993 and 1 September 1994. Data included yield (adjusted to 13% seed moisture), days to anthesis (50% flowering), plant height (ground to tip of panicle), 100-seed weight, and harvest index. Agronomic and harvest data were statistically analyzed by analysis of variance and means were compared by the LSD procedure, using SAS (1985).

## RESULTS AND DISCUSSION

The mean grain yield for the 10 hybrids was 5,020 kg/ha. We found highly significant differences between years, with 1993 producing greater mean yields than 1994. Highly significant yield differences among hybrids were detected. No significant Year X Hybrid interaction was detected. Of the 10 hybrids, four exceeded yields of 5,000 kg/ha, while the remaining hybrids produced yields above 4,000 kg/ha (Table 2). Yields ranged from 6,240 (Cargill Ma Cau 90) to 4,185 kg/ha (Cargill Apollo). These yields compare favorably with sorghum yields reported by Fox et al. (1974), Wahab et al. (1976), Sotomayor-Ríos and Weibel (1978), and Sotomayor-Ríos and Torres-Cardona (1984). Sotomayor-Ríos et al. (1980) compared 12 maize hybrids and selections and found

TABLE 2.—Year and hybrid means and coefficient of variation (C.V.) of grain yield, days to anthesis, plant height (ht), 100-seed weight (wt) of ten sorghum hybrids planted at the Fortuna Substation Farm, Juana Díaz, during 1993 and 1994.

Hybrid	Grain yield kg/ha	Days to anthesis	Plant ht. (cm)	100-seed wt (g)	Harvest index (%)
Cargill Ma Cau 90	6240.3 a <sup>1</sup>	63.0 bcd	160.2 a	4.15 a	33.0
DK-65	5458.2 ab	61.3 cd	148.3 bc	3.89 b	32.4
DK-77	5063.9 bc	64.0 bcd	157.2 ab	3.33 de	29.9
DK-73	5011.5 bc	67.3 a	152.3 ab	2.86 g	28.3
Cargill Mart 85	4970.9 bc	64.5 abc	154.0 ab	3.51 cd	30.9
DK-64	4960.5 bc	61.0 d	137.5 d	3.37 de	32.7
Pioneer 8240	4946.2 bc	64.5 abc	140.7 cd	3.21 ef	33.3
Cargill Jupiter	4813.7 bc	65.8 ab	154.3 ab	3.22 ef	29.9
Pioneer 8200	4486.9 c	64.8 ab	150.2 abc	3.08 f	29.7
Cargill Apollo	4185.6 c	63.3 bcd	149.2 bc	3.64 c	29.9
1993	5271.1 a	71.0 a	161.2 a	2.73 b	21.6 b
1994	4693.3 b	56.9 b	139.6 b	4.50 a	40.1 a
Mean	5020.3	63.9	150.4	3.44	31.0
C. V., %	15.1	4.3	5.9	3.85	12.1
Hybrid LSD (0.05)	955.6	3.2	10.4	0.18	4.4
Year LSD (0.05)	429.6	3.3	4.7	0.08	1.9

<sup>1</sup>Means within a column followed by one or more letters in common do not differ significantly at P < 0.05 by the Least Significant Difference.

yields ranging from 3,012 (PR-3) to 6,229 (Pioneer 304C) kg/ha. Quiles-Belén et al. (1985) evaluated 27 maize germplasm populations and cultivars of board genetic backgrounds at the Isabela Experiment Farm of the Tropical Agriculture Research Station, USDA-ARS. They reported grain yields from 6,407 to 3,516 kg/ha, respectively. Sorghum yields reported here compare favorably with the maize yields previously reported by these authors.

Significant differences existed between hybrids in days to anthesis with values ranging from 67 (DK-73) to 61 (DK-64) days (Table 2). Highly significant differences were observed between years, with hybrids in 1993 taking longer to flower than in 1994. Highly significant and negative correlations were found between days to anthesis and harvest index and seed weight (Table 3). A highly significant positive correlation was also observed between days to anthesis and plant height. Highly significant differences in plant height were found for both years and hybrids. In 1993, plants were significantly taller than in 1994. Plant heights ranged from 160.2 (Cargill Ma Cau 90) to 137.5 (DK-64) cm.

TABLE 3.—Pearson correlations for yield and other agronomic characteristics of ten sorghum hybrids planted at Fortuna Substation Farm, Juana Díaz, in 1993 and 1994.

	Yield	Plant height	Panicle length	Days to anthesis	Harvest index	Desired score	Seed weight
Yield		.344 <sup>1</sup>	.019	.190	-.179	-.215	-.030
Plant height			.217	.699 <sup>2</sup>	-.708 <sup>2</sup>	-.086	-.584 <sup>2</sup>
Panicle length				-.001	-.046	-.125	.087
Days to anthesis					-.859 <sup>2</sup>	-.203	-.906 <sup>2</sup>
Harvest index						-.171	.864 <sup>2</sup>
Desire score							-.284
Seed weight							

<sup>1</sup>Significant at 0.05 probability level.

<sup>2</sup>Significant at 0.01 probability level.

Seed weight is an indication of relative seed size; and it has been shown that sorghum seed size is significantly and negatively correlated with seed number per panicle (Miller et al., 1976). Mean 100-seed weights for the ten hybrids was 3.44 g and ranged from 4.15 g (Cargill Ma Cau 90) to 3.08 g (Pioneer 8200) (Table 2). Highly significant Year X Hybrid interactions were detected which indicate that environmental differences between years influenced the rate of seed size. Though the seed weight of top yielding Cargill Ma Cau 90 was greater than the mean, no significant correlation between yield and seed weight was observed (Table 3). Highly significant negative correlations were found for seed weight and both days to anthesis and plant height. Seed weight was significantly and positively correlated to harvest index.

High yields obtained from sorghum hybrids can be partially attributed to the enhanced vegetative and reproductive components of the plants. DeFrança (1990) reported that increased yields produced by new superior sorghum hybrids as opposed to older hybrids were due in part to increased harvest indices. As harvest index increased, a greater proportion of photoassimilate was partitioned into the panicle and the grain. No significant differences were detected among hybrids for harvest index, although 1993 had significantly lower harvest indexes than 1994 (Table 2). Harvest index was significantly and negatively correlated to days to anthesis and plant height, and significantly and positively correlated to seed weight (Table 3). Yearly differences in almost all agronomic measurements may have been a result of the different climatic conditions between the two years. The year 1993 was characterized by heavier rainfall, cloudier days, and cooler temperatures.

These results obtained from small plots cannot be extrapolated directly to commercial scale grain farming; however, they provide evidence to the effect that there is an abundance of sorghum germplasm with high yielding potential which should be tested in commercial production. These high yield potentials suggest that Puerto Rico could be less dependent on imported feed grains.

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