Forage Sorghum Response to N Fertilization and Harvest Intervals[1]

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ABSTRACT

Differences between locations, hybrids, N levels, cutting intervals and cuttings, and interactions of locations × hybrids, locations × N, locations × cutting intervals, locations × cuttings, cutting × N, and cutting intervals × N were significant for most traits in a study of the effect of N applications and cutting intervals on dry forage and crude protein yields, crude protein content, plant height and leaf area of three sorghum-sudangrass hybrids (*Sorghum bicolor* L. Moench) at two locations in Puerto Rico. Treatments included side-dressed N at 0, 80 and 160 kg/ha and three cutting intervals of 60, 75 and 90 days. Dry forage yields increased significantly with N fertilization, especially with the initial increment and with cutting intervals. Crude protein content was highest at 60 days and diminished as cutting interval increased. A three-way forage hybrid (A Tx624 × B Rhodesian sudan) × Common sudan produced the highest dry forage and crude protein yields and crude protein content compared with the single-crosses A Tx23 × Greenleaf sudan and A Tx624 × Common sudan.

INTRODUCTION

Limited research has been conducted in Puerto Rico on the effect of N fertilization and harvest intervals on forage sorghum, *Sorghum bicolor* (L.) Moench.

Vázquez et al. (11) reported the effect of three nitrogen levels on the dry forage yields of local variety Millo Blanco in a study conducted in southwestern Puerto Rico. The intermediate 89.6 kg/ha (80 lb/acre level) outyielded the lower level. The curve of forage yield versus N application tended to level off with the higher 134.3 kg/ha (120 lb/acre) N treatment. However, the latter outyielded the intermediate N treatment for the last three cuttings.

Numerous studies in Puerto Rico have shown that sorghum is a forage crop with great potential in tropical areas. Excellent yields of more than 20 tons/ha of dry forage in 180 days, with a crude protein content of more than 12%, have been obtained with the best hybrids (3–8, 10).

This study was undertaken to evaluate three N levels and three cutting intervals on dry forage and crude protein yields, plant height and leaf area of three forage hybrids at two locations in Puerto Rico.

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MATERIALS AND METHODS

The experiment was conducted in 1981 in an Oxisol (Tropeptic Haplorthox, clayey, kaolinitic, isohyperthermic) at the Isabela experiment farm of the Tropical Agriculture Research Station (TARS), USDA, ARS, S&E and in a Vertisol (Udic Chromustert very fine, montmorillonitic, isohyperthermic) at the Lajas Research and Development Center of the Agricultural Experiment Station, University of Puerto Rico. The experimental variables were three N rates, three cutting intervals, three forage sorghum hybrids and two locations. The general characteristics of the experimental sites were as follows:

	Isabela	*Lajas*
Location	Northwestern PR	Southwestern PR
Latitude	18°30′ N	18°0′ N
Longitude	67° W	67° W
Temperature range	18.8-29.4°C	22.6-31.4°C
Elevation	128 m	33 m
Annual rainfall	1,675 mm	1,194 mm
Soil	Oxisol (Coto)	Vertisol (Fraternidad)
Organic matter content	3%	2.5%
Exchange capacity (meq./100 g soil)	23	35
pH	5.1	6.3
P (p/m)	111	63
K (p/m)	67	50
NO_3 (p/m)	10	28

Fertilizer treatments consisted of 0, 80 and 160 kg N/ha applied as ammonium sulfate at planting, and immediately after each of the three cuttings. Before planting, P and K were each applied to all plots at a rate of 100 kg/ha each. The three forage sorghum hybrids studied were A Tx623 × Greenleaf sudangrass, A Tx624 × Common sudangrass, and (A Tx624 × B Rhodesian sudangrass) × Common sudangrass. The first two are single crosses whereas the third is a three-way hybrid. Hereafter, the hybrids will be referred to as A Tx623 × Greenleaf, A Tx623 × Common, (A Tx624 × B Rhodesian) × Common.

The experimental design was a split-plot arrangement of randomized complete blocks with four replications. Each plot consisted of two rows, 6 m long, spaced 1.0 m apart. Hybrids were the main plots, cutting intervals the sub-plots and N levels the sub-sub-plots.

Three cuttings were made at harvest intervals of 60, 75 and 90 days.

Before each cutting, measurements were made of plant height (from the ground to the midpoint of the upper leaf blade), leaf blade area (using the second leaf blade from the top and multiplying maximum length × maximum width × 0.747 × number of leaves/plant). This calculation has been reported to give a close approximation to leaf area as determined by a planimeter (9). Yields of dry forage (DF) and crude protein (CP) were calculated for each cutting. Samples were analyzed for dry matter (DM) and crude protein contents (CPC), Analysis of variance and regression techniques were utilized in the interpretation of the data.

RESULTS AND DISCUSSION

The combined analysis of variance showed significant differences between locations, hybrids, N levels, cutting intervals and cuttings, and significant interactions of locations × hybrids, locations × N, locations × cutting, harvest × N, and cutting intervals × N for most traits. The over-all DF yields of the three forage sorghum hybrids at the 60-day interval were higher at Lajas than at Isabela (fig. 1). The DF yields of the hybrids increased with increasing N rates at the two locations. At Lajas, the mean DF cutting yield of (A Tx624 × B Rhodesian) × Common increased from 7.51 when no N was applied to 9.09 tons/ha with 160 kg N/ha. However, the DF yield from the intermediate N level to the maximum level increased by 3%. Over 28 tons/ha of DF were produced in three cuttings by the three-way hybrid at Lajas. The response of A Tx624 × Common was similar to that of the three-way hybrid. At Isabela the DF yields were also highest with the three-way hybrid, and increased from 6.02 to 7.48 tons/ha with applications of 0 and 160 kg N/ha, respectively. Similar responses to N applications were observed in the other hybrids. At no N the DF yields of A Tx624 × Common and A Tx623 × Greenleaf were lower than that of the three-way hybrid.

The DF yields at the 75-day harvest interval showed a similar pattern to those of the 60-day interval. Yields increased sharply with N rates up to the maximum tested of 160 kg N/ha in the three grasses at the two locations. The DF yields of the three-way hybrid and that of A Tx624 × Common were higher than that of A Tx623 × Greenleaf.

Leaves of the plants harvested at 90-day intervals were affected by diseases such as rust, *Puccinia purpurea* Cooke, zonate leaf spot, *Gloeocercospora sorghi* Bain and Edgerton, and to a lesser extent by anthracnose, *Colletotrichum graminicola* (Ces.) G. W. Wils. At Lajas the effect of foliage diseases was more evident on A Tx624 × Common. At both locations the DF yields of the three-way hybrid increased sharply with N rates up to the maximum tested of 160 kg/ha. The DF yields of hybrids A Tx624 × Common and A Tx624 × Greenleaf increased from 6.88 and 6.60 when no N was applied to 10.37 and 9.74 tons/ha, respectively, in

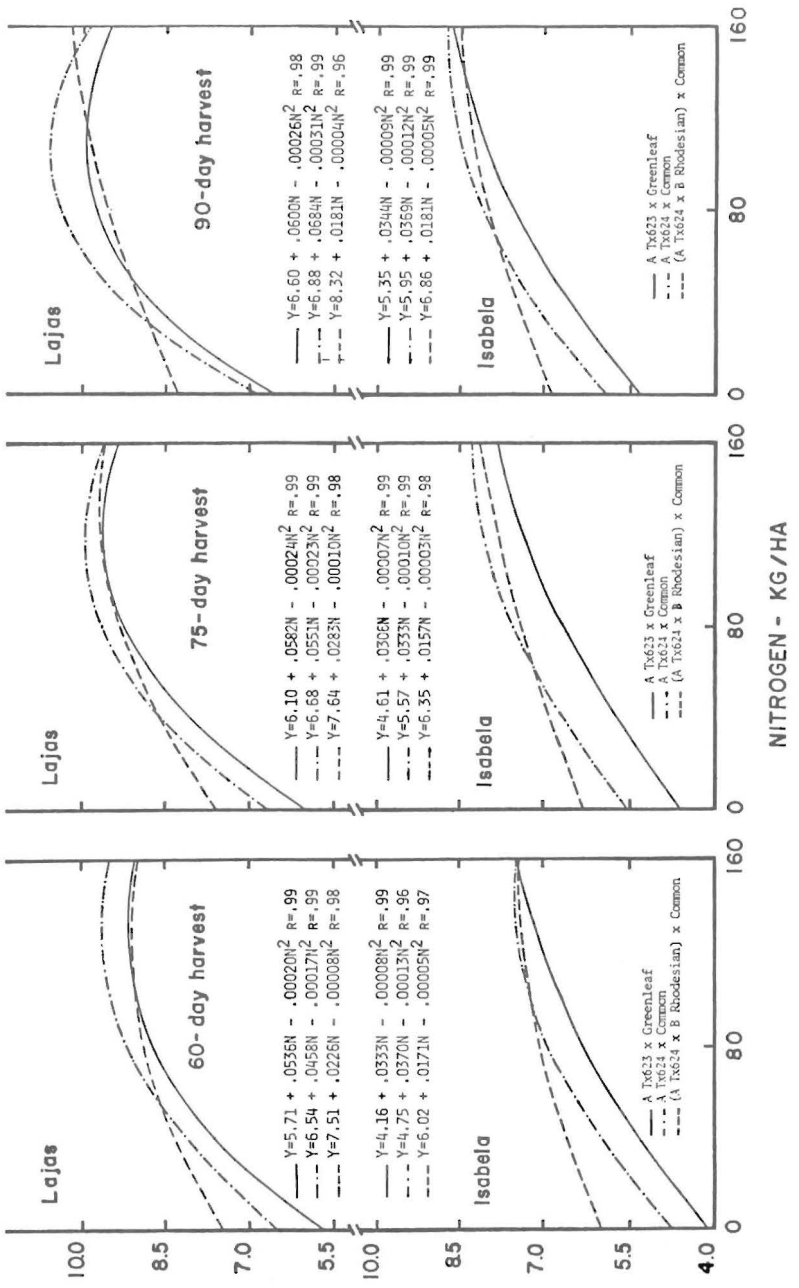

FIG. 1.—Relationship between nitrogen levels and dry forage yield of three forage sorghum hybrids. 1982.

the intermediate N level. However, the DF yields of these two hybrids decreased from the intermediate to the maximum N level. The three-way hybrid was less affected by the foliar diseases than A Tx624 × Common and A Tx623 × Greenleaf at Lajas. At Isabela the foliar diseases were less severe than at Lajas, especially with the 75- and 90-day harvest intervals. Also, at Lajas many plants were affected by downy mildew, *Sclerospora sorghi* (Kulk) Weston and Uppal, when about 4 weeks old. This disease was controlled by frequent applications of captan {N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide} and metalaxyl [N-(2,6-dimethylphenyl)-N-(methoxyacetyl)-alanine methyl ester].

The mean CPC of the forage was highest at 60 days and diminished as the cutting interval increased (fig. 2). Over-all CPC's of the hybrids were higher at Lajas than at Isabela (8.60 vs. 8.03%). At Lajas, at the 60-day cutting interval the mean CPC of the hybrids was 34% higher with the application of 80 kg N/ha than without N fertilization. The application of 160 kg N compared with 80 kg N/ha increased the over-all CPC by only 3%. At Isabela, on the other hand, and at the 60-day cutting interval, the mean CPC of the hybrids was 90% higher with the intermediate than with the 0 application. The over-all CPC of the hybrids increased 10% between the intermediate and high N levels. At the 75- and 90-day harvest intervals, similar trends were observed both at Lajas and Isabela. Greater differences were observed at Isabela for these harvest intervals. The over-all CPC's of the hybrids at the 80 kg N/ha level were 116 and 115%, respectively, relative to those with no N applied. The over-all mean CPC of the three individual hybrids generally followed a similar pattern. It increased sharply from no N up to the application of 80 kg N/ha but increased slightly less with the higher N level.

The over-all CP yields of the hybrids were higher at Lajas than at Isabela. The best CP yield at the 60-day harvest interval was that of three-way hybrid (A Tx624 × B Rhodesian) × Common. The CP yield increased markedly with N rates up to the maximum of 160 kg/ha in all three hybrids at both locations. Crude protein yields of the three-way hybrid increased at Lajas from 1.85 for three harvests combined with no N was applied to 3.07 tons/ha with the maximum N application. The CP yield response of single cross A Tx624 × Common at Lajas and Isabela was very similar to that of the three-way hybrid. As to A Tx623 × Greenleaf, at Lajas the CP yield increased from 1.34 (no N) to 2.94 tons/ha with the maximum N level, whereas at Isabela corresponding figures were 0.66 to 2.59 tons/ha (fig. 3).

Previous studies at Isabela (3, 7, 10) have shown that plant height is an important trait highly associated with yield. At the 60-day cutting interval, plants were higher at Lajas than at Isabela. In all three hybrids

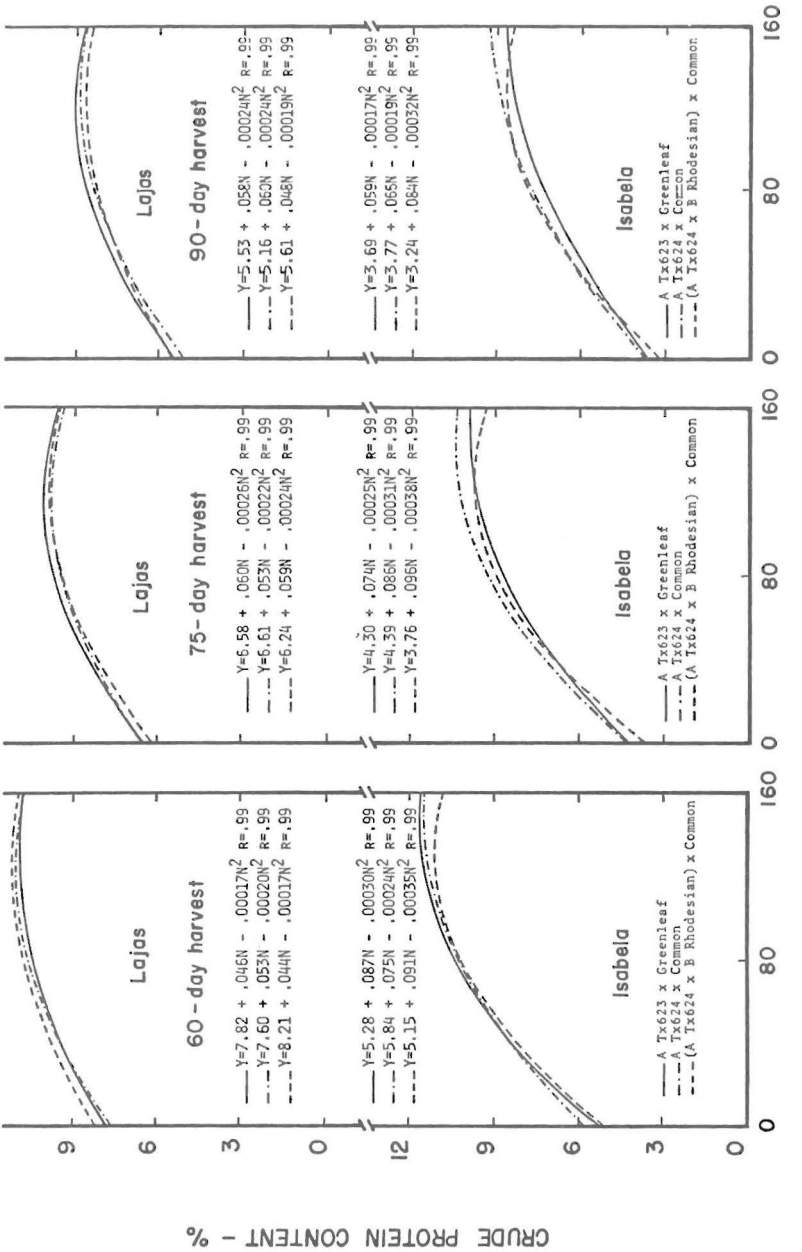

FIG. 2.—Relationship between nitrogen levels and crude protein content of three forage sorghum hybrids. 1982.

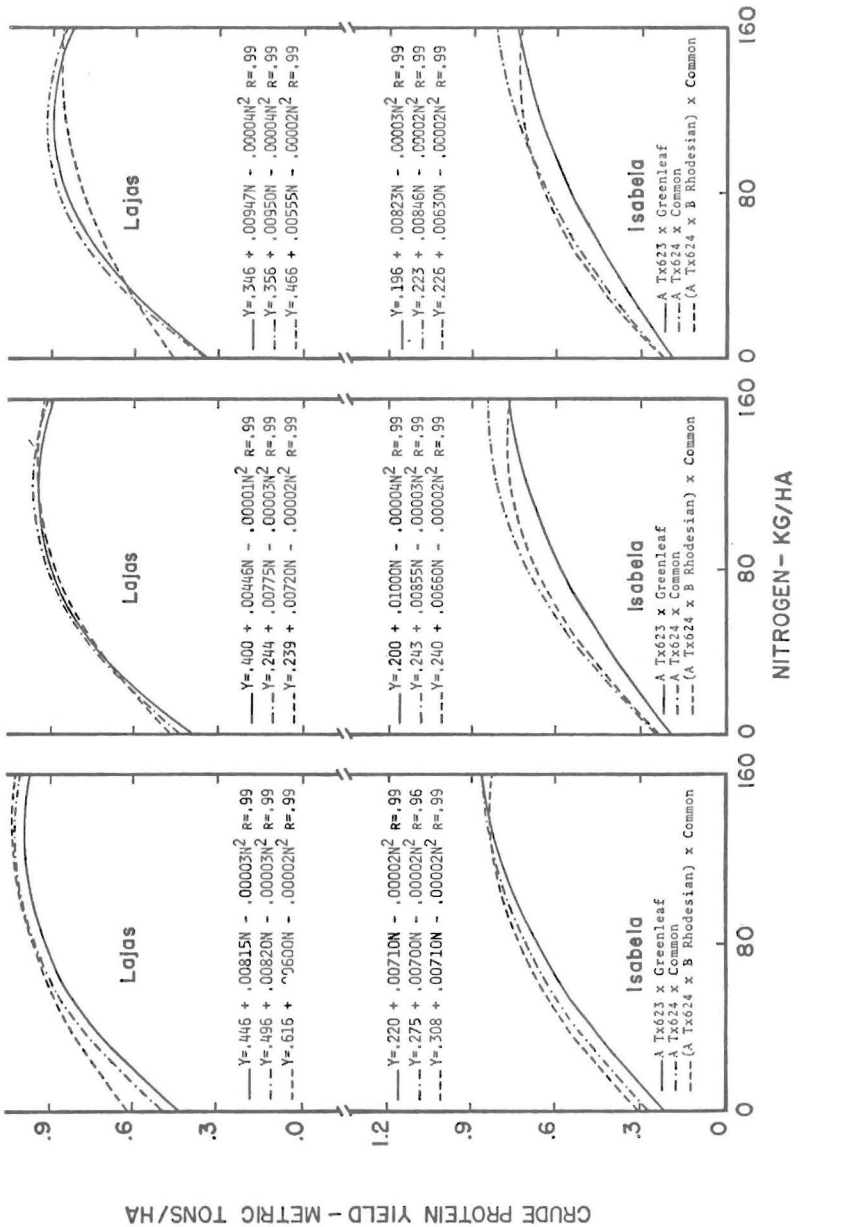

FIG. 3.—Relationship between nitrogen levels and crude protein yield of three sorghum hybrids. 1982.

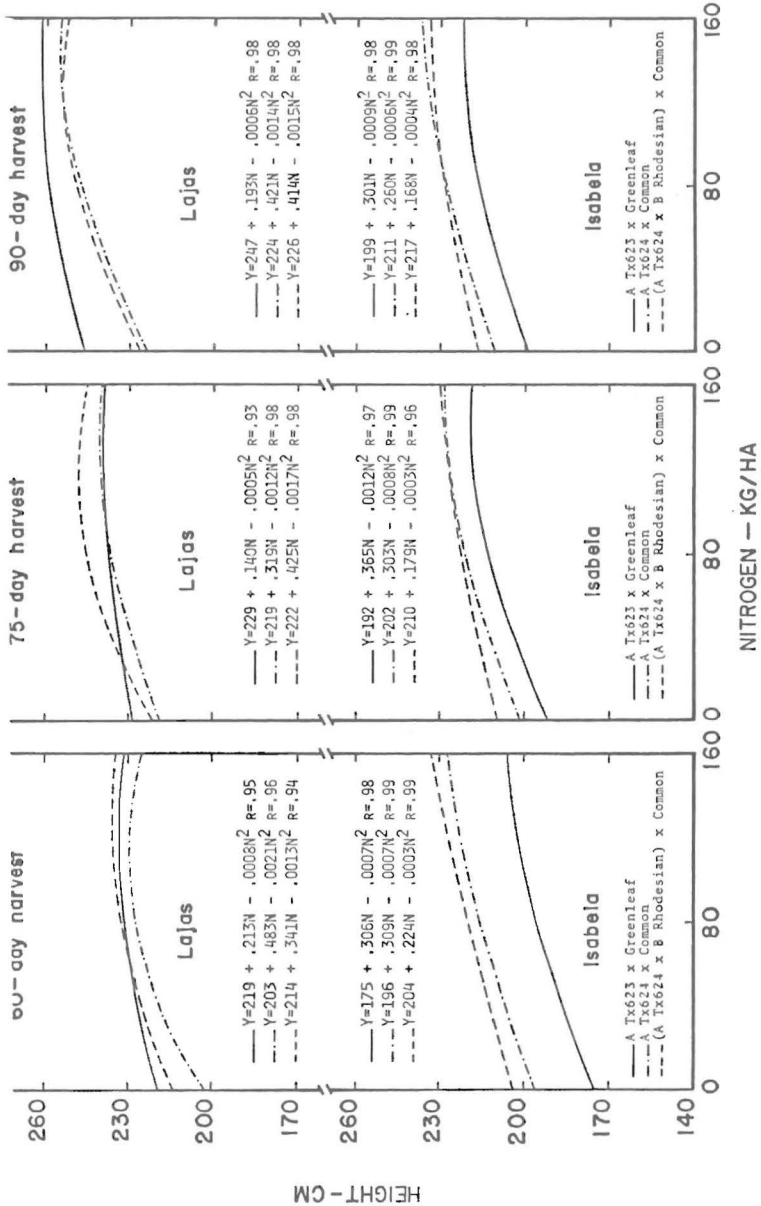

FIG. 4.—Relationship between nitrogen levels and plant height of three forage sorghum hybrids. 1982.

height increased sharply with N fertilization up to the maximum level tested. Three-way hybrid (A Tx624 × B Rhodesian) × Common height increased from 204 cm when no N was applied to 233 cm with 160 kg N/ha (fig. 4). The response of increased plant height to higher N application at the 75-day harvest was very similar for all three hybrids at both locations. Plants were tallest at the 90-day cutting interval and the response to N followed a pattern similar to that for the 75-day cutting. Again, the hybrids were taller at Lajas than at Isabela.

As in previous studies (3, 7, 10) the association of leaf area (LA) with forage yields was consistent, which indicates that this trait might become an important selection criterion for forage improvement. The LA value of the three hybrids at the 60-day cutting interval was higher at Lajas than at Isabela. The three-way hybrid had the highest LA. It increased sharply with N rates from 6154 cm^2 when no N was applied to 8341 cm^2 with the intermediate application of 80 kg N/ha. The LA of the three-way hybrid decreased with the maximum N application relative to the intermediate level. The remaining two hybrids had similar response curves, but their LA values were considerably below those of the three-way hybrid. At Isabela the LA curves of the three hybrids increased steeply with N rates up to 160 kg N/ha (fig. 5). The over-all LA of the three grasses at the 75-day cutting interval was higher at Lajas than at Isabela. The three-way hybrid had the highest LA value. It increased from 6639 cm^2 when no N was applied to 8511 cm^2 with the intermediate application of 80 kg N/ha; it decreased thereafter with the maximum application of N. The LA of A Tx624 × Common increased continuously with N rates up to the maximum tested, but that of A Tx623 × Greenleaf decreased from the intermediate to the maximum level of 160 kg N/ha. The LA value of the three-way hybrid was considerable lower at Isabela than at Lajas. At the 90-day cutting also the LA value of the three-way hybrid was higher at Lajas than at Isabela. It increased from 6659 cm^2 when no N was applied to 9155 cm^2 with the intermediate application of 80 kg N/ha and then decreased, as in previous cutting intervals, with the maximum N application of 160 kg/ha. The LA of A Tx624 × Common and A Tx623 × Greenleaf increased markedly from no N up to the intermediate N application. At Isabela the LA of all three hybrids increased with N rates up to the maximum.

Studies have been conducted in Puerto Rico on the effect of cutting interval on yield and protein content of tropical grasses (12). It has been concluded that most tropical grasses should be cut about every 45 days during seasons of flush growth and every 60 days during the slower winter growth. Napiergrass (*Pennisetum purpureum* Schum.), the species most affected by frequency of cutting, yields almost three times more dry forage when cut at 90 days, and twice as much as 60 days, than when cut

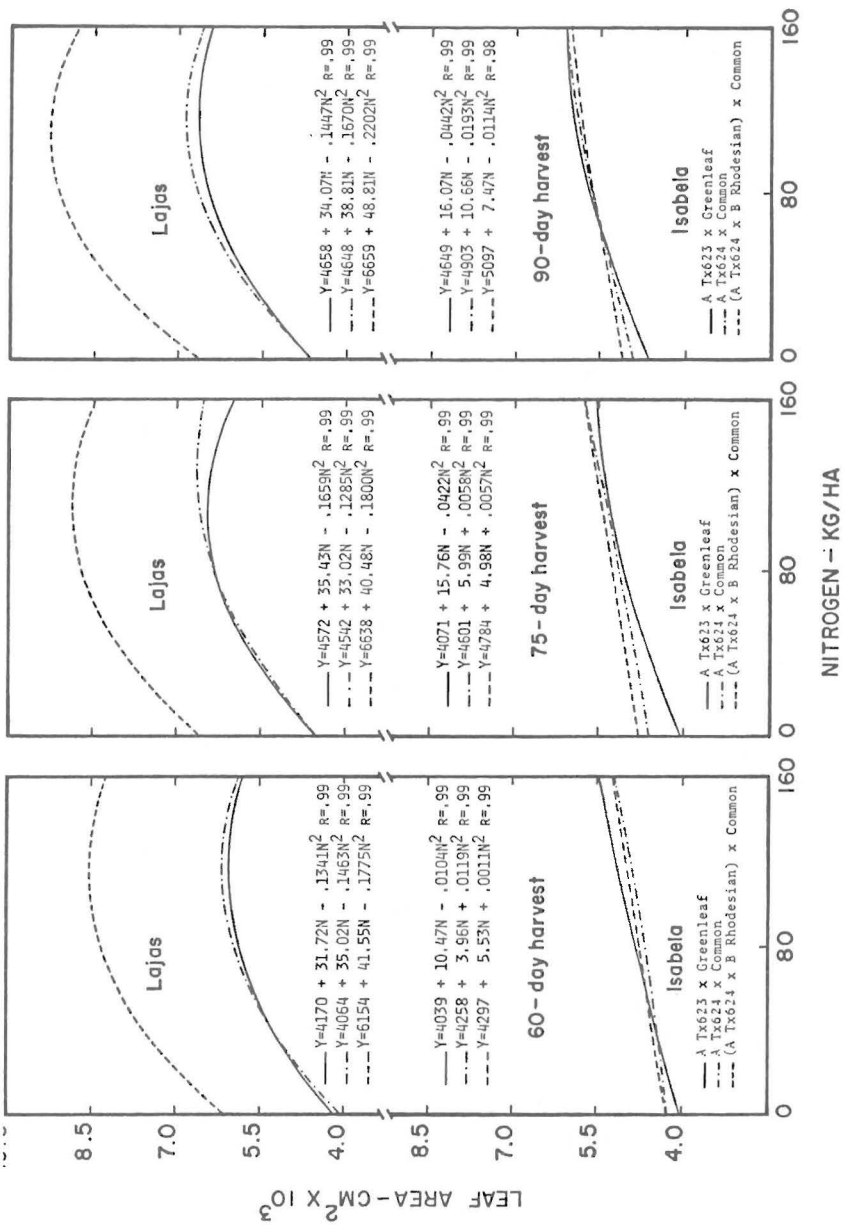

FIG. 5.—Relationship between nitrogen levels and leaf area of three forage sorghum hybrids. 1982.

at 40-day intervals. However, few reports are available on the effect of cutting interval on yield and protein content of forage sorghum (1, 2).

In a 1-year study conducted near Santa Isabel, Puerto Rico, Caro-Costas (1) evaluated four forage sorghums under irrigation. Yields of all forages increased with each increase in cutting interval averaging 23, 40 and 55 tons of DF/ha when harvested every 30, 45 and 60 days, respectively. Crude protein content of the forage showed the opposite trend averaging 8.9, 6.2 and 5.2 percent for the 30-, 45- and 60-day cutting intervals, respectively.

Extensive studies comparing forage sorghum (Sordan 70A, a commercial hybrid developed by Northrup King) with Napiergrass (Common), two Napiergrass hybrids and sugarcane (*Saccharum officinarum*, PR-980) as short-rotation candidates for biomass production, have been conducted at the Center for Energy and Environmental Research of the University of Puerto Rico.[3] Cutting intervals were 60, 120 and 180 days. Preliminary data showed that Sordan 70A outyielded the remaining species at the 60-day interval. At the 120- and 180-day harvest intervals, Sordan was outyielded by Napiergrass but was better than PR-980.

Figure 6 shows the effect of cutting interval on dry forage yield at each of the three N levels. Over-all DF yields were higher at Lajas than at Isabela when no N was applied. At this N level the DF yields increased sharply with cutting intervals up to 90 days. At Isabela the DF yield increased 11 and 22% at 75 and 90 days, respectively, in relation to the 60-day interval. At Lajas the same increases were only 2.5 and 8.2%, respectively. At the intermediate level of N application (80 kg/ha), DF yields were lower at Isabela than at Lajas at each of the cutting intervals. At Lajas the DF yield increased 7 and 12% at 75 and 90 days, respectively, in relation to the 60-day interval. The increase from 60 to 90 days was only 5%. At the highest N level (160 kg/ha) DF yields at different cutting intervals followed a pattern similar to that described for the intermediate N level.

Table 1 shows the effect of N levels from three applications on CPC over locations, hybrids and cutting intervals. The CPC increased continuously from 5.48 to 9.82% from no N to the high N application. In relative terms, the CPC increase was 69 and 79%, with the intermediate and high N applications, respectively. The CP yield also increased with increasing N applications. Relative to no N these increases were 35 and 45%, respectively, with the intermediate and high N applications. The highest increase was obtained with the application of a total of 240 kg N/ha, whereas an additional 240 N units produced an increase of only

[3] Production of sugarcane and tropical grasses as a renewable energy source. 1979. First and second quarterly reports to DOE, Year 3, DOE Contract No. DE-AS05-78ET20071.

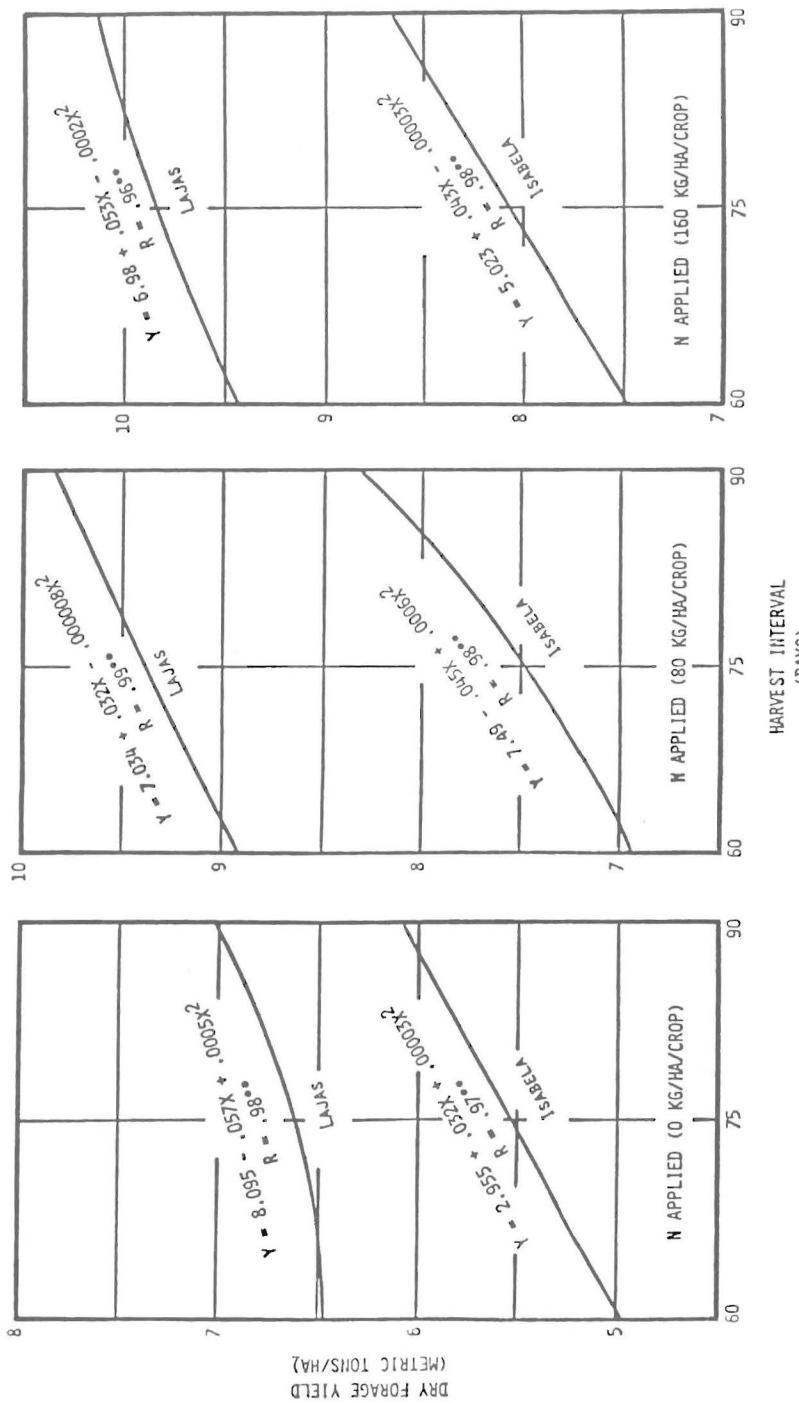

FIG. 6.—Dry forage yields of three sorghum hybrids by locations and N rates at three cutting intervals. 1982.

61%. A large amount of N was removed from the soil in the absence of N fertilization (163 kg). With the application of 240 kg/ha of N, 370 kg/ha were removed. Application of 480 kg/ha of N resulted in less N being removed from the soil than the amount applied. Fertilizer N recovery in the forage was 86.3% at the 240 kg/ha level of application and decreased to 52.8% at the highest N application.

TABLE 1.—*Effect of N levels over locations, hybrids and cutting intervals*[1]

Total N applied	Crude protein content	Relative increase	Dry forage yield	Increase	Relative N removed	Fertilizer N recovered in the forage
kg/ha	%		*t/ha*	%	*kg/ha*	%
0	5.48	100	18.59	100	163.0	—
240	9.24	168	25.04	135	370.1	86.3
480	9.82	179	26.49	142	416.2	52.8

[1] Data represent mean of 4 replications, 3 cutting intervals, 3 harvests and 2 locations in Puerto Rico.

TABLE 2.—*Approximate costs of producing forage sorghum in the southern region of Puerto Rico*[1]

Item	Cost $/ha
Seedbed preparation	136.00
Planting and seed	79.00
Application of herbicide	10.00
Application of fertilizer	25.00
Application of water	49.00
Cutting, chopping and transportation (45 tons/ha oven dry at $22.00/ton)[2]	990.00
Miscellaneous wages	25.00
Fertilizer (560 kg/ha per cutting)	576.00
Herbicide	49.00
Water—.74 ha/m	89.00
Social Security, Health Insurance, etc.	62.00
Land rental/ha/year	124.00
Interest on working capital	49.00
Total cost	2,263.00
Total cost/ton of dry forage	50.28

[1] Average dry forage yield of the best hybrid (A Tx624 × B Rhodesian) × Common (60-day cutting interval) was 9.09 tons/ha (Lajas) and 8.09 tons/ha (Isabela).

[2] Based on 5–6, 60-day cuttings.

ECONOMIC CONSIDERATIONS

Table 2 shows the approximate cost of producing forage sorghum in the south coast of Puerto Rico. Because this experiment shows that the best forage sorghum hybrids can produce more than 9 tons/ha every 60 days, dry forage yields are estimated at about 45 tons/ha. The cost/ha for cutting, chopping and transporting the 45 tons is $2,263 at $50.3/ton of dry forage. If a 20 to 25% wastage of chopped forage is assumed, total

yearly yields/ha of forage sorghum consumed would be about 34 tons. Vicente-Chandler et al. (12) have shown that well-managed grass pasture can provide all the nutritional requirements of a 550-kg cow that produces 10 liters of milk daily. Although it has not yet been determined what level of milk production can be obtained from green chopped forage sorghum, a theoretical yield of 8 kg/day can be safely assumed. Corresponding TDN requirements would be 4.35 kg for maintenance plus 2.9 kg for milk production (8 × .36), giving a total of 7.25 kg daily. Under these conditions, each kilogram of milk requires 0.9 kg of TDN. As a rough estimate, it can be assumed that 34 tons of dry forage/ha with 50% TDN content could provide the necessary nutrients to produce 18,889 kg of milk/ha. In Puerto Rico this would have a market value of approximately $8,311 ($.44/kg). Assuming that the forage accounts for one third of the cost of producing milk, total production costs can be estimated at $6,789, thus the net profit from growing forage sorghum for milk production would be $1,552/ha yearly ($8,311–$6,789).

CONCLUSIONS

Dry forage yield of three sorghum hybrids increased in curvilinear fashion with three increasing levels of N fertilization and three increasing cutting intervals. Crude protein content increased with N level, but diminished as cutting interval increased. Plant height of all hybrids increased with N levels. Leaf area increased from no N up to the intermediate N level, but decreased thereafter. Regression techniques showed that quadratic equations adjusted the data adequately. The R values for all traits studied varied from 94 to 99%. A rough estimate of net profit from growing forage sorghum in Puerto Rico for milk production is $1,522.00/ha.

RESUMEN

Se estudió el efecto de cantidades de N e intervalos de corte sobre la producción de forraje y proteína bruta, el contenido en proteína bruta, la altura de la planta y el área foliar de tres híbridos sorgo-sudán. El nitrógeno se aplicó a 0, 80 y 160 kg/ha y los cortes se hicieron cada 60, 75 y 90 días. El experimento se hizo en dos localidades de Puerto Rico. Las diferencias fueron significativas entre localidades, híbridos, cantidades de nitrógeno, intervalos de corte y cosechas y entre las interacciones de localidades × híbridos, localidades × N, localidades × intervalos de corte, localidades × cosechas, cosechas × N, e intervalos de corte × N para la mayoría de las características estudiadas. La producción de forraje seco aumentó significativamente, especialmente con la aplicación inicial de N, y con los intervalos de corte. El contenido en proteína bruta fue más alto a los 60 días y disminuyó según aumentó el intervalo de corte. El híbrido

triple (A Tx624 × B Rhodesian sudan) × Common sudan registró la mayor producción de forraje seco y proteína bruta y contenido en proteína bruta en comparación con los cruces sencillos A Tx624 × Common sudan. Se estima que a base de la información obtenida la ganancia neta proveniente del sorgo forrajero para producir leche puede ser de $1,522.00/ha.

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