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The effect of stocking rate, fertilizer level and winter supplementation on the grazing performance of Senepol purebred and crossbred bulls[1]

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ABSTRACT

The study consisted of a grazing and a grazing plus supplemental feeding phase. Forty-eight Senepol purebred and crossbred bull calves were assigned to the following treatments: T1: stocking rate (SR) 3.45 animals per hectare and 449.1 kg/ha of fertilizer; T2: T1 plus winter supplementation; T3: SR 1.85 animals per hectare and 224.5 kg/ha of fertilizer; and T4: T3 plus winter supplementation. The bulls were supplemented with a mix of poultry litter, molasses and corn grain at the onset of seasonal restrictions on pasture growth. During the grazing phase the effect of pasture management on average daily gains (ADG) and closing weights was not significant ($P > 0.05$). However, moderate pasture management systems (T1 and T2) produced 218 kg more weight gain per hectare ($P < 0.05$). Winter supplementation increased ($P < 0.05$) ADG; total weight gains per bull; and weight gains per hectare (+0.32 kg/animal/day; +37.1 kg/animal; +104.4 kg/ha of weight gain). Bulls in T2 and T4 consumed daily 2.33 and 1.44 kg of supplement dry matter (DM) per animal and had estimated feed conversions of 6.65 and 5.90 kg of

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DM per kilogram of added gain (P > 0.05), respectively. Herbage mass decreased continuously and was significantly lower (P < 0.05) at the end of the trial. The mean production cost of the total weight gain for the entire study was $0.08/kg lower in T2 than in T1. Within supplemented treatments, animals grazing at a SR of 3.45 animals per hectare (T2) had the lowest cost per kilogram of gain.

Key words: strategic supplementation, poultry litter, grass-fed beef, Senepol bulls

RESUMEN

Efecto de la carga animal, nivel de abono y suplementación invernal sobre el desempeño a pastoreo de toretes Senepol puros y cruzas

El estudio consistió de una fase de pastoreo y otra fase de pastoreo con suplementación. Cuarenta y ocho toretes Senepol puros y cruzas se asignaron a los siguientes tratamientos: T1: carga animal (CA) de 3.45 animales por hectárea y 449.1 kg/ha de fertilizante; T2: T1 más supplementación invernal; T3: CA de 1.85 animales por hectárea y 224.5 kg/ha de fertilizante; y T4: T3 más suplementación invernal. La dieta de los animales se suplementó con una mezcla de camada de pollo, melaza de caña y maíz partido al comienzo del segundo invierno a pastoreo. Durante los primeros 321 días de la fase de pastoreo, el efecto del sistema de manejo de la pastura sobre la ganancia diaria en peso (GDP) y pesos finales no fue significativo (P > 0.05). Sin embargo, los toretes pastando a CA moderadas (T1 y T2) produjeron un total de 218 kg más de ganancia en peso por hectárea (P < 0.05). La suplementación invernal aumentó significativamente (P < 0.05) la GDP; la ganancia en peso por animal y los kilogramos de aumento en peso por hectárea (+0.32 kg/animal/día; +37.1 kg/animal; +104.4 kg/ha de aumento en peso). Los toros en T2 y T4 consumieron diariamente 2.33 y 1.44 kg de materia seca (MS) de suplemento por animal y mostraron conversiones estimadas de 6.65 y 5.90 kg de MS por kilogramo de ganancia en peso debida al suplemento (P > 0.05), respectivamente. La cantidad de forraje disponible en las pasturas declinó de forma continua y fue significativamente más baja (P < 0.05) al final del estudio. El costo promedio del kilogramo de aumento en peso para ambas fases del estudio (pastoreo y pastoreo con suplementación) fue $0.08/kg más bajo en T2 que en T1. Los animales suplementados y pastando bajo CA de 3.45 animales por hectárea (T2) tuvieron el menor costo por kilogramo de aumento en peso.

INTRODUCTION

Beef production is based on grass-fed systems in many tropical areas of the world where grains and their by-products are expensive. Tropical climates with their long photoperiods and copious precipitation possess the environmental conditions necessary for abundant grass growth. Grass-fed cattle have leaner carcasses and higher muscle to fat ratios that follow consumer preferences and changes in eating habits based on health considerations. However, animals grazing tropical grasses show low to moderate average daily gains (ADG), restricting the ability of bulls to reach processing weights at a younger age, lengthening the feeding period, and compromising the profits of the cattlemen and the quality of the final product (Mott and Moore, 1977; Poppi and Mclennan, 1995). The performance of grazing animals is limited by the low digestible energy and protein content of tropical grasses and the seasonal variations that further affect the quality and quantity of pasture on offer (Lippke and Ellis, 1989). Ultimately, variations in climatic conditions can impose nutritional restrictions on grazing cattle when least expected, at any time of the year.

During the 70s and 80s, research conducted to intensify beef production in Puerto Rico underscored the use of heavy applications of fertilizer on grass pastures managed under rotational grazing (Caro-Costas et al., 1976; Caro-Costas and Vicente-Chandler, 1972; Caro-Costas and Vicente-Chandler, 1981). Low cattle prices along with the high costs associated with fertilization and the subdivision of pastures with fences have dissuaded beef producers from implementing this system. An economic outlook of the previous research was provided by Antoni et al. (1992), who studied the effect of stocking and fertilization rates upon the economic returns of stargrass based beef production systems. These researchers reported that, for the price scenario prevailing at the end of the study, the combination of 3.6 animals and 890 kg/ha of fertilizer resulted in the highest profit.

Supplemental feeding, another alternative to improve growth rates of grazing animals, has already started in many regions of the Island where some type of by-product is readily available to the cattlemen. Feed supplements can provide nutrients that are limited, or supply needed energy or protein during periods of forage restriction or of greater requirements for growth. Furthermore, many agricultural and industrial waste materials considered pollutants could be used as a source of low cost nutrients for grazing cattle, thus helping to reduce waste disposal problems. Supplemental feeds used strategically can promote growth in a cost-effective manner improving the efficiency of production, the quality of grass-fed beef, and consumer demand for the local product.

MATERIALS AND METHODS

The study was conducted at the Isabela Substation of the Agricultural Experiment Station, University of Puerto Rico, located in the northwest coastal region of the island. Annual mean temperature ranges between 20 and 24° C. Rainfall distribution is good for most of the year, with a dry season extending through January, February and March. Average rainfall varies between 8.13 and 19.05 cm per month.

An area of 19.89 ha of guinea grass *(Panicum maximum Jacq.)* pastures was selected for the study and divided into three 6.63-ha blocks. Each experimental block was then subdivided according to treatment randomization into four paddocks to fit 16 bull calves in four treatment groups of four calves each. Forty-eight Senepol purebred and crossbred bull calves of similar age and nutritional background were put on test at a mean age of 10 months. The bulls were ranked by weight and randomly assigned to the four treatments within blocks. All animals were individually weighed, ear-tagged, and treated for internal and external parasites. Weighing took place every 28 to 35 days, after 14 to 16 hours without feed and water. Treatments consisted of T1: cattle grazing at a stocking rate (SR) of 3.45 animals per hectare and 449.1 kg/ha of fertilizer; T2: T1 plus supplement during the winter months; T3: cattle grazing at a SR of 1.85 animals per hectare and 224.5 kg/ha of fertilizer; and T4: T3 plus supplement during the winter months. Fertilizer (15-5-10) was applied once in the month of November, before the start of the trial.

The study started January 1996 and consisted of a grazing and a grazing plus supplemental feeding phase. The initial phase had a duration of 321 days, during which time the animals grazed according to pasture management system. By the end of fall, supplementation started for the bulls in T2 and T4. During the first week the amount of supplement fed daily was gradually increased from 1 to 2.27 kg/animal. After 76 days of feeding, the supplement offered in T2 was increased to 4.54 kg/animal in view of the extremely low pasture availability and faltering ADG. Bulls in the low SR and fertilizer level (FL) treatment (T4) were less inclined to consume the supplement, and after 55 days of feeding their daily consumption decreased to 1.8 kg/animal for the rest of the period. Orts were removed every other day and weighed. Throughout the trial the bulls grazed continuously and at fixed SR.

The ingredients of the supplement mix were 33% sugarcane molasses, 10% corn grain, 55% poultry litter and 2% of a trace mineral and vitamin premix. The supplement was mixed weekly and group-fed daily in the paddocks. At least one linear foot of feedbunk space was offered per bull. To minimize the possibility of forage substitution the initial amount of supplement provided per day was estimated from the difference between the known ADG possible under this SR and FL, and the new target ADG. For these calculations net energy for gain (NE_g) and net energy for maintenance (NE_m) requirements of medium frame size bulls were used (NRC, 1984). A 5% increase in the NE_m requirement of the bulls was incorporated into the estimate to account for environmental stress, and maximum dry matter (DM) intake was assumed to be 2.5% of body weight. The crude protein (CP), NE_m and NE_g concentration of the supplement was predicted by using tables of composition of feeds (NRC, 1984) for the corn (IFN 4-02-931) and molasses

(IFN 4-04-696), and from average values of previously analyzed local samples of poultry litter.

Pastures were sampled monthly from July 1996 to March 1997 to determine DM, CP content and pasture availability. Samples for DM and CP determinations were hand plucked, oven dried and ground through a Wiley mill fitted with a 1-mm screen, and a composite was prepared within season. Herbage mass was estimated monthly by clipping a pasture area of 1 m^2, 15 cm above ground level from two randomly selected sites in each paddock.

Statistical analysis

The experimental design was a complete randomized block with three replications. The response variables evaluated were initial and final weights (FW); ADG; weight gain per animal; supplemental feed conversion (kilograms of supplement DM per kilogram of additional weight gain); beef production per hectare; stocking weight (SW) (kilograms of liveweight per hectare); and pasture dry matter availability (PDMA) (kilograms of DM/m^2). Data on animal performance and production per unit of area collected during the grazing phase were analyzed by pooling T1 and T2, and T3 and T4 as a complete randomized block design with two treatments and six replications. An analysis using four treatments and three replications was also performed to establish that before the supplemental feeding phase there were no significant differences between treatments under the same pasture management system. Terms in the model for the animal performance and production per unit of area response variables were an overall mean and the main effects of treatment (T) and block (B). The class variables included for the analysis of the PDMA data were, in addition to T and B, month (M) and the interaction of T × M. All data were analyzed by using the GLM procedures of SAS (1996). The Duncan Multiple Range test was used to compare differences among T means.

Economic evaluation

The economic evaluation of the production systems was performed through partial budget analysis. The budgets covered the following cost factors: land rent, labor, fertilization, supplement, depreciation of structures and equipment, and interest on operational, animal, fence and structure costs. Grazing area size, SR, quantity of fertilizer applied, animal performance and supplemental feeding were expected to influence differences among treatments. The cost per kilogram of weight gain was used to compare the economic efficiency of the four feeding systems.

RESULTS AND DISCUSSION

Grazing phase

Initial weights at the start of the grazing trial averaged 255.4 kg and were not significantly different among groups (Table 1). After 321 days of grazing the effect of pasture management on ADG and closing weights was not significant ($P > 0.05$). Nevertheless, treatments T1 and T2 produced 218 kg more weight gains per hectare ($P < 0.05$), than T3 and T4 (Table 1). This additional gain represented a 62.8% increase in beef production per land unit. Dufrasne et al. (1994; 1995) evaluated the effects of SR, period of supplementation at pasture and shelter on the grazing performance of Belgian Blue bulls. After four consecutive years of grazing trials they concluded that increasing SR decreased ADG while increasing the total liveweight gain per hectare.

During this phase of the study ADG was relatively low in both pasture management systems (Table 1). Bulls in T3 and T4 with more forage available and smaller SW ($P < 0.05$) (Table 1) did not show significantly higher gains per day than the animals in T1 and T2. These results suggest that pasture DM availability was not the factor that limited the ADG of the bulls while grazing without supplement. Low dry matter consumption has been reported in animals consuming forages low in CP (Carnevali et al., 1970; Fall et al., 1989). Pasture samples collected the last six months of this phase presented CP contents that ranged from 7.7 to 8.6% in summer and from 7.23 to 7.63% in fall. These values are close to the minimum levels recommended for adequate rumen function (Matejovsky and Sanson, 1995) yet below the CP concentration in the diet necessary to achieve satisfactory ADG. Medium frame bulls weighing 318.2 to 409.1 kg require at least 8.6 to

TABLE 1.—*Initial and closing weights, average daily gains and kilograms of gain per hectare, stocking weights and pasture dry matter availability during the grazing phase*[1].

	Initial weights kg	Closing weights kg	ADG[2] kg/head/day	Weight gains per hectare kg/ha	Stocking weight[3] kg live-weight/ha	Pasture DM availability kg DM/m^2
T1 & T2	254.79 a[4]	418.13 a	0.509 a	564.47 a	1,163.47 a	0.165 b
T3 & T4	255.93 a	443.17 a	0.583 a	346.55 b	647.54 b	0.197 a

[1]321 days of grazing from 12 January to 4 December 1996.
[2]ADG = Average daily gain during grazing without supplement.
[3]SW= [0.5(average initial weight + average closing weight)] × stocking rate
[4]Means in the same column with different letters differ significantly ($P < 0.05$).

10.1% CP in their diets to gain from 0.68 to 0.91 kg/day (NRC, 1984). Growing bulls that graze summer and fall pastures of chemical composition similar to that of the pastures in this study could benefit from an additional source of ruminally degradable protein or nonprotein nitrogen (NPN) in their diets to improve their grazing performance (pasture DM intake and ADG).

Table 2 presents the means for ADG, SW and PDMA of the analysis performed to compare treatments within pasture management system (four treatments and three replications). No significant differences (P > 0.05) were found between T1 vs. T2 and T3 vs. T4 for the three response variables, thus suggesting that paddocks within pasture management systems had similar quality and quantity of pasture on offer. Consequently, in the supplemental feeding phase that followed any difference found between comparable supplemented and nonsupplemented treatments should be attributed to the effect of the supplement.

Grazing plus supplemental feeding phase

Supplemental feeding was initiated in December 1996 and lasted for 118 days. Supplement consumption increased ADG significantly (P < 0.05) in both pasture management systems (Table 3). ADG and total weight gains per bull were on average 0.32 and 37.1 kg per head higher (P < 0.05) in these treatments. Differences in weight gains between T2 and T4 were not significant (P > 0.05). According to extensive reports in the literature, the performance of animals grazing or consuming forages deficient in quality or quantity has improved when their diet has been supplemented with sources of CP and energy (Bowman et al., 1995; Derouen et al., 1993; Essig et al., 1994; Hennessy et al., 1981; Horn et al., 1995; Lake et al., 1974; Lippke and Ellis, 1989; Randel and

TABLE 2.—*Average daily gains, stocking weights and pasture dry matter availability during the grazing phase*[1].

	ADG[2] kg/head/day	Stocking weight[3] kg liveweight/ha	Pasture DM availability kg DM/m²
T1	0.510 a[4]	1,157.92 a	0.172 bc
T2	0.509 a	1,169.03 a	0.158 c
T3	0.595 a	648.38 b	0.193 ab
T4	0.570 a	649.78 b	0.203 a

[1]321 days of grazing from 12 January to 4 December 1996.

[2]ADG = Average daily gain during grazing without supplement.

[3]SW= [0.5(average initial weight + average closing weight)] × stocking rate

[4]Means in the same column with different letters differ significantly (P < 0.05).

TABLE 3.—*Average daily gains and average weight gains per bull and hectare, stocking weights, and pasture dry matter availability during winter grazing and supplemental feeding*[1].

	ADG[2] kg/head/day	Weight gain kg/bull	Weight gains per hectare kg/ha	Stocking weight kg live-weight/ha	Pasture DM availability kg DM/m²
T1	0.15 c	17.6 c	60.8 c	1,472.4 a	0.110 ab
T2 + supplement	0.53 a	62.0 a	214.4 a	1,558.7 a	0.090 b
T3	0.33 b	38.3 b	71.0 c	860.0 b	0.142 a
T4 + supplement	0.58 a	68.1 a	126.2 b	876.3 b	0.114 ab

[1]118 days from 4 December 1996 to 1 April 1997.
[2]ADG = Average daily gain.
[3]Means in the same column with different letters are significantly different ($P < 0.05$).

Mendoza, 1983; Sanson et al., 1990). Supplementation also significantly increased ($P < 0.05$) the intensity of production (Table 3). Animals in T2 and T4 produced 153.6 and 55.2 kg more weight gain per hectare ($P < 0.05$) than bulls in T1 and T3, respectively. Similar results were reported by Horn et al. (1995) and Phillips et al. (1995), who increased stocking densities, SR and beef production per hectare by feeding supplements to grazing animals.

Daily supplement consumption per animal was 2.33 and 1.44 kg of DM in treatments T2 and T4, respectively. Supplemented bulls in the low SR treatment (T4) refused 5.7% of the supplement throughout the feeding period and were never offered more than 1.87 kg of supplement DM per bull per day. On the contrary, bulls in T2 after the first week of feeding consumed all the supplement provided, with no refusals, and were fed up to 3.74 kg of DM. Differences in SW and PDMA may have been responsible for the lower supplement consumption of the bulls in T4. At the end of the grazing phase the animals in T4 compared to those in T2 had 44.4% less SW ($P < 0.05$) and 28.4% more forage DM available ($P < 0.05$) (Table 2). Under these conditions of lower grazing pressure, supplement consumption was less attractive to the animals in T4. Wagnon (1966) evaluated the effect of social dominance and supplemental feeding in range cows, and reported that the percentage of nonfeeders was positively related to forage availability.

The estimated conversion rate of the supplement (kilograms of supplement DM per kilogram of additional gain) was 6.65 and 5.90 ($P > 0.05$) for the bulls in T2 and T4, respectively. Lower supplement to added gain ratios, indicative of a large increase in the efficiency of pasture or protein utilization, were not expected in this study because the mean CP content

(8.17%) of the winter pastures was within the minimum required for normal rumen function. Furthermore, pasture DM availability in T4 and T2 ranged from low to very low (Table 3), and the additional CP provided to the animals was essentially NPN. Extremely low conversion rates (kilogram of supplement per kilogram of gain above control) of 2.74 to 3.35 and 1.94 to 1.05 have been reported for weanling and yearling steers grazing Bermudagrass pastures and supplemented with 28% CP condensed molasses blocks, or yearlings fed cottonseed and fish meal based supplements, respectively (Derouen et al., 1993; Lippke and Ellis, 1989).

Adequate nitrogen levels are needed in the rumen for a satisfactory digestion. Several studies have shown improvements in the intake of low nitrogen fibrous diets due to CP supplementation (Smith et al., 1980; Sriskandrajah et al., 1982). For the most part, CP supplements increase DM intake in animals consuming forages containing less than 7 to 8% CP (Matejovsky and Sanson, 1995; Sanson et al., 1990) allegedly as a result of correcting a nitrogen deficiency in the rumen (DelCurto et al., 1990). A strong positive associative effect is common when animals that graze pastures of low digestibility and protein content, but of adequate DM availability, are supplemented with protein of natural origin (Marston and Lusby, 1995; Veira et al., 1995). The additional protein increases DM consumption by improving harvesting efficiency (grams of forage intake per kilogram of bodyweight per minutes spent grazing), digestion rate, fiber digestibility, and by decreasing retention time in the rumen (Beaty et al., 1994; Krysl and Hess, 1993; Muinga et al., 1995; Sunvold et al., 1991).

In this study the supplement provided daily to each animal an additional 1.79 and 1.10 Mcal of NE_g, and 0.40 and 0.25 kg of CP (mostly NPN) in T2 and T4, respectively.[8] Even if during the winter months low CP values had induced a nitrogen deficiency in the rumen, the lack of pasture availability (Table 3) would have hindered any increase in pasture DM intake due to improved digestion rate. Furthermore, most of the weight gain attributed to supplemental feeding can be accounted for by the energy provided by the supplement. Average daily gains recorded above control in T2 were 7.32% lower, whereas in T4 were 0.80% higher, than values predicted from supplement DM consumption and NE_g content.[9] The supplement appeared to make a contribution to the

[8]Nutrient composition of the supplement: 17.3% CP; 1.35 Mcal/kg DM of NE_m; 0.768 Mcal/kg MS of NE_g.

[9]Predicted ADG: T2 =0.406 kg; T4=0.250 kg; LWG=15.54 $NE_g^{0.9116}$ $W^{-0.6837}$. Prediction equation for live weight gain (LWG) from net energy for gain (NE_g) in medium frame bulls. Nutrient Requirements of Beef Cattle, Sixth revised edition 1984, National Academy Press, Washington, DC.

energy nutrition and provided, together with the pasture, enough crude protein for that energy to be used efficiently. At this level of pasture DM restriction, no substitution is believed to have occurred.

There was a significant effect ($P < 0.05$) of pasture management on the ADG of bulls in the nonsupplemented treatments (Table 3). Animals in T3 gained 0.18 kg more per head per day ($P < 0.05$) than the bulls in T1, which with a higher SR, SW, and no winter supplementation had the lowest ADG ($P < 0.05$) of all groups. During this phase PDMA decreased 37.2% in T1 but only 26.4% in T3, while SW increased in both groups 27.0 and 32.6%, respectively, with respect to the grazing phase (Table 2). At this stage of the grazing trial the low ADG displayed by the nonsupplemented groups was the result of insufficient PDMA, which restricted the energy and crude protein intake of the bulls (Delcurto et al., 1990; Munro and Walters, 1986). Overall, herbage mass was significantly lower ($P < 0.05$) in the winter than in the months of summer and fall. Casas et al. (1997) and Vicente-Chandler et al. (1974) have reported similar results with animals grazing tropical grasses.

Overall performance

At the end of the trial, ADG and FW were higher in the treatments that received supplemental feeding (T2 and T4) and in the low SR and FL group (T3) than in T1 (Table 4), but these differences were significant ($P < 0.05$) only between T4 and T1. Weight gains produced per hectare favored the moderate over the low SR treatments. T1 and T2 produced an average of 259 kg more weight gains per hectare ($P < 0.05$) than T3 and T4. Supplemental feeding had a greater effect on the intensity of production in the moderate than in the low SR treatments. Differences in weight gains per hectare among treatments, within pas-

TABLE 4.—*Overall average daily gains, final weights, weight gains per hectare and pasture dry matter availability.*

	ADG[1] kg/head/day	Final weights kg	Weight gains per hectare kg/hectare	Pasture DM availability kg DM/m²
T1	0.41 b[2]	434.3 b	627.2 b	0.14 bc
T2 + supplement	0.51 ab	481.5 ab	777.6 a	0.12 c
T3	0.52 ab	483.8 ab	425.5 c	0.17 a
T4 + supplement	0.57 a	506.8 a	461.5 c	0.16 ab

[1]ADG = Average daily gain.

[2]Means in the same column with different letters are significantly different ($P < 0.05$).

ture management systems, were significant between T2 and T1 (777.6 vs. 627.2 kg/ha), yet not significant between T4 and T3 (461.5 vs. 425.5 kg/ha). The bulls in T2 at 1.87× the SR of T3 finished the trial with similar FW and ADG ($P > 0.05$), but produced 82.7% more kilograms of beef per land unit ($P < 0.05$) on account of only 118 days of supplementation in a 439-day grazing period.

Herbage mass was significantly lower ($P < 0.05$) at the end of the trial (January, February and March) than at the beginning (August, September, October, and November). PDMA measured in December was significantly different ($P < 0.05$) from that in September, February and March, the period that presented the lowest recorded PDMA ($P < 0.05$). These results reflect the cumulative effects that continuous grazing, fixed SR and increasing SW had on pasture availability, and were accentuated in the winter months by the seasonal restraints on pasture growth. There were no significant differences ($P > 0.05$) in PDMA between treatments under the same pasture management system (Table 4). Among treatments, however, T3 and T4 had significantly greater ($P < 0.05$) herbage mass than T2. Differences between T4 and T1 and the T × M interaction were not significant ($P > 0.05$).

Economic evaluation

Production costs and the cost of the weight gain for the four production systems are presented in Table 5. Land rent and labor costs represented more than 56% of the total feeding costs in all systems. The most important production cost was labor in T1 and T2, and land rent in T3 and T4. In the moderate SR treatments the cost of land rent expressed as a percentage of the total cost was 12.8% lower than in the extensive SR systems. Land rent and labor reached 69% of the total production costs in T3 under low SR and no supplemental feeding. These results indicate the need to look for ways to economically increase the number of animals per land unit in order to reduce fixed costs per animal and increase production. Fertilizer was the third major production cost, ranging from 12.60 to 14.40% and 10.30 to 10.90% in treatments T1-T2 and T3-T4, respectively.

Supplemental feeding successfully increased the economic efficiency of beef production in the moderate pasture management system (Table 5). Cost per kilogram of gain in T2 was $0.08 lower than in T1. Within supplemented treatments, animals under moderate SR had the lowest cost per kilogram of gain, thus suggesting again the economic inefficiency of extensive production systems and the need to evaluate the use of cost effective supplements to increase not only production per animal but the number of animals per unit of land. Similar conclusions are

TABLE 5.—*Production costs considered for the economic evaluation and cost per pound of gain of the feeding systems*[1].

	T1		T2		T3		T4	
	$/bull	%	$/bull	%	$/bull	%	$/bull	%
Land rent[2]	69.6	24.1	69.7	20.5	130.2	36.7	130.3	33.6
Labor[3]	119.2	41.3	131.3	38.5	119.3	33.5	127.7	32.9
Materials[4]								
Fertilizer	34.2	11.9	34.2	10.1	32.0	9.0	32.0	8.2
Herbicide	5.7	2.0	5.7	1.7	7.6	2.1	7.6	2.0
Medicines	2.0	0.7	2.0	0.6	2.0	0.6	2.0	0.5
Supplement	0.0	0.0	29.4	8.6	0.0	0.0	18.1	4.7
Depreciation[5]								
Fence	15.7	5.5	15.7	4.6	21.5	6.1	21.5	5.5
Structures	2.3	0.8	2.8	0.8	2.3	0.7	2.8	0.7
Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interest								
Operational costs	12.6	4.4	22.5	6.6	12.6	3.6	18.8	4.8
Fencing	0.7	0.2	0.7	0.2	0.9	0.3	0.9	0.2
Animals	26.1	9.0	26.5	7.8	26.2	7.4	26.6	6.9
Structures	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Total cost	$288.3		$342.7		$355.1		$388.4	
Cost/kg of gain	$1.59		$1.51		$1.55		$1.55	

[1]Budgets prepared for each treatment based on 12 bulls grazing 3.46 ha (T1 and T2) or 6.48 ha (T3 and T4). Costs do not include depreciation of pastures and feed mixer.

[2]Land rent: $80/0.405 ha.

[3]Labor cost: 20 h/month (T1 and T3) and 22 h/month (T2 and T4) at $4.89/h (does not include time spent mixing the supplement).

[4]Cost of materials: fertilizer $0.26/kg; herbicide $75/treatment/year (T3 and T4) and $56.25/treatment/year (T1 and T2); medicines $2.00/head; supplement $0.09/kg (ingredients and mixing).

[5]Depreciation of: fences, 6 years (investment in T1 and T2 = $1,008.70 and T3 and T4 =$1379.16, approximately $0.413 per linear foot); corrals, waterers and feedbunks, 20 years (investment in T1 and T3 = $500 and T2 and T4 = $600).

[6]Interest on operational costs includes labor, fertilizer and herbicide.

found in the literature stressing the economic benefits of supplementing grazing animals, only when necessary and in appropriate amounts (Houseal and Olson, 1996; Kee et al., 1995; Osuji, 1987; Phillips et al., 1995).

CONCLUSION

Supplemental feeding of bulls grazing under the pasture management and environmental conditions present in this study improved

ADG and FW of the animals. This practice was more effective in the moderate (3.45 animals per hectare) than in the low SR system (1.85 animals per hectare), where weight gain per hectare was significantly increased ($P < 0.05$) by supplementation. The economic efficiency of beef production was also successfully improved in the moderate SR system. Bulls in T2 grazing at 3.45 animals per hectare showed the lowest cost per kilogram of gain. No substitution effect was observed for the supplement. Overall, results favor supplementation strategies in Puerto Rico when there is a restriction in the quality or quantity of forage. The need to evaluate the use of cost-effective supplements to improve production per animal and per unit of land is emphasized.

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