Influence of season and stocking rate on pasture herbage availability and milk yield[1,2]

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ABSTRACT

This experiment evaluated the effect of season of the year and stocking rate (SR) on pasture availability to lactating dairy cows supplemented with concentrates. In study 1, herbage mass (HM) and pasture allowance (PA) were evaluated on a commercial dairy farm during the months of July to February. Regression analysis indicated a significant and quadratic negative relationship between time and HM ($P < 0.05$; $R^2 = 0.65$) and a weaker linear relationship between time and PA ($P < 0.05$; $R^2 = 0.47$). Herbage mass and PA were lower from October to February, when the climate is dryer and cooler in the Caribbean tropics. Pasture allowance declined from 48.7 (July to September) to 21.1 kg/cow (December to February). However, estimated pasture consumption increased from 6.4 to 8.1 kg of dry matter per cow over the same period. In a second study, the effect of SR on HM, PA and concentrate supplementation was evaluated on 12 farms. As expected, HM ($P < 0.05$; $R^2 = 0.31$) and PA ($P < 0.01$; $R^2 = 0.80$) declined as SR increased. There was no significant relationship between SR and concentrate intake (CI) or between CI and milk yield. On most farms pasture herbage appeared to be underutilized because of relatively high levels of concentrate supplementation. Pasture management and supplementation strategies should be modified to account for seasonal variability of pasture yield and intake. This modification would improve nutrient utilization from pasture and would reduce the need for purchased feeds and ultimately ration costs.

Key words: dairy cows, tropical grasses, pasture allowance, concentrate supplementation

RESUMEN

Influencia de la estación y la carga animal sobre la disponibilidad de forraje y la producción de leche

Este trabajo se realizó para evaluar el efecto de la época del año y la carga animal (CA) en la disponibilidad de pasto a vacas lecheras suplementadas con concentrados. En un primer estudio se evaluó la producción de forraje por hectárea (PF) y el pasto disponible por vaca (PD) durante los meses de julio a febrero. Un análisis de regresión de los datos indicó una rela-

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ción negativa y cuadrática ($P < 0.05$; $R^2 = 0.65$) entre mes y PF y una relación negativa de menor grado entre mes y el PD ($P < 0.05$; $R^2 = 0.47$). La PF fue menor durante los meses de octubre a febrero, cuando el clima es más seco y fresco. El PD se redujo de 48.7 kg/día (julio a septiembre) a 21.1 kg/día (diciembre a febrero). Sin embargo, el consumo diario estimado de pasto aumentó de 6.4 (julio a septiembre) a 8.1 kg/vaca (diciembre a febrero) de materia seca. En un segundo estudio, se evaluó en doce hatos el efecto de la CA en la PF, el PD y la suplementación con concentrado. Según lo esperado, la PF ($P < 0.05$; $R^2 = 0.31$) y el PD ($P < 0.01$; $R^2 = 0.80$) se redujeron a medida que aumentó la CA. No se observó una relación entre CA y el consumo de concentrado o entre este último y la producción de leche. De acuerdo con estos resultados en la mayoría de las fincas evaluadas el pasto fue subutilizado debido principalmente al alto consumo de alimento concentrado. El manejo de los pastos y las estrategias de suplementación deben ser modificados de acuerdo con la variabilidad estacional en el rendimiento y consumo del pasto. Esta modificación mejorará la utilización de nutrientes del pasto y redundará en reducciones en el costo de la ración.

Palabras clave: apacentamiento, vacas lechera, gramíneas tropicales, pasto disponible, suplementación con concentrados

INTRODUCTION

Dairying is one of the most important agricultural activities in the Caribbean. In Puerto Rico, current trends indicate that the number of dairy farms is declining and the average herd size is increasing correspondingly. Furthermore, the land area dedicated to pasture production has declined by more than 12% in the last 10 years (ORIL, 2004). In the tropics, the availability and nutritive value of pasture consumed by lactating dairy cows change throughout the year with marked differences observed between the hot summer and cooler winter months. However, reliable data documenting these changes and their effect on lactational performance in a tropical environment are few, particularly under conditions of high concentrate supplementation.

Concentrate supplementation increases milk yield (MY) compared to yield with no concentrate supplementation in cows with the ability to respond (Kennedy et al., 2003; Vicente-Chandler et al., 1983). However, increasing supplementation above minimum recommendations has not resulted in further increases in MY, particularly for cows producing less than 20 kg of milk daily (Vicente-Chandler et al., 1983; Ruiz et al., 2001). This investigation was undertaken to evaluate the effect of season of the year and stocking rate (SR) on pasture availability and intake by dairy cows supplemented with concentrates at a high level.

MATERIALS AND METHODS

Trial 1

Experimental Farm—A commercial dairy farm located in the northwest region of Puerto Rico was selected for the study on the basis of herd size, location and willingness of the farmer to cooperate with this research. On average, the farm milked about 120 Holstein cows daily. Paddocks of mostly stargrass (*Cynodon nlemfuensis*) were rotationally grazed throughout the period of evaluation. Pastures were irrigated regularly with wastewater from the lagoon and were fertilized yearly with approximately 1,100 kg/ha of fertilizer 15-5-10, in three applications. In addition to grazing, all cows were supplemented with about 2.0 kg of alfalfa hay and 9.2 kg of commercial concentrate daily throughout the experimental period. Most (7.5 kg) of the daily concentrate allotment was fed in two equal portions during each of the two milkings, and the rest (1.7 kg) was fed together with the hay prior to the p.m. milking in a holding area.

Pasture Evaluation and Sampling—A geographical information system (GIS) was constructed for the whole farm. The area of individual paddocks used in the rotation by the lactating herd was estimated by using this information. These pastures, predominantly of stargrass, with a few patches of *Urochloa mutica* and *Eriochloa polystachia*, were evaluated for yield and chemical composition from July to February. Pasture herbage of the farm was sampled nine times, for two days each time, during the evaluation period. At each sampling, we determined herbage mass (HM) at 15 cm above ground level prior to grazing the next paddock in the rotation, utilizing the calibrated disk method (Santillan et al., 1979). Pasture allowance (PA) was determined by dividing the number of cows in the paddock by the total pasture dry matter (DM) or HM on offer (HM × paddock area). Individual paddocks were grazed daily for a period of four hours a.m. and eight hours p.m., once every 15 days. A second determination of HM was made for each paddock the morning after grazing to estimate forage above 15 cm not consumed during grazing. Since paddocks were grazed for only one day (12 h), we found that the calibration curve obtained to estimate HM prior to grazing also worked best for estimating HM after grazing.

Pasture intake was determined as the difference between HM before and after grazing. Daily pasture intake per cow was estimated by dividing total pasture DM consumed by the number of cows grazing on the paddock. Stocking rate was defined as animal units (AU) per hectare, where one AU equals 454 kg of live weight. It was assumed that an adult lactating Holstein cow weighed 545 kg. Only lactating cows in the herd and the area used for their grazing were used to calculate SR.

Sample and Data Analysis—During each visit to the farm, we took a sample of pasture herbage (simulated grazing), hay and concentrate feed for analysis of chemical composition. These samples were dried in a convection oven at 65° C for 48 h, ground in a Wiley Mill through a 2-mm sieve and stored in a freezer until further analysis. Samples were composited according to season and sent for analysis of chemical composition to the Dairy One Laboratory (Ithaca, NY).[6]

For discussion of the results, the experimental period was divided and categorized into seasons, which were defined as follows: summer (July to September), fall (October to November), and winter (December to February). To determine the effect of time of the year on HM and PA, we grouped dates into weekly periods from July (weeks 1 to 4) to February (weeks 29 to 32). Regression analysis was utilized to evaluate the data (Freund and Littell, 1991).

Trial 2

Twelve additional pasture-based commercial dairy farms were selected on the basis of location, SR, and availability of records (enrolled in the PR Dairy Herd Improvement Association and participating in the USDA-NRCS program). Feeding and grazing management on these farms were studied to evaluate the effect of SR on HM, PA, and concentrate supplementation. Farms were selected to represent the two major dairy areas of the Island. All farms used rotational grazing management of tropical grasses. The predominant grass species present in the pastures of all farms was stargrass, with smaller areas or intermixtures of pangola (*Cynodon dactylon*), guineagrass (*Urochloa maximum*), paragrass (*Brachiaria mutica*), and caribgrass (*Eriochloa polystachya*) being present in most cases. Each farm was visited once during the three-month period from May to July.

We obtained information on pasture management, area utilized for grazing, number of grazing cows, amount and type of supplements being fed, and MY through interviews and the use of a questionnaire filled out by each dairyman. All the dairies used a similar feeding management, typical of pasture-based dairies, where most of the concentrate was fed in the milking parlor. Most dairies fed supplemental forage and concentrate during late morning prior to the p.m. milking. The type and amount of concentrates and other supplements used was recorded for each dairy the day of the visit. We assumed these values represented their typical feeding management practices.

At the sampling visit to each farm, we determined HM prior to grazing. As in Trial 1, we took samples of pasture herbage, harvested forages and concentrates to determine chemical composition. We estimated total dry matter intake (DMI) by using an empirical equation developed by Ruiz (unpublished) using local data with cows managed

[6]Name of laboratory service was mentioned to provide specific information and does not constitute a warranty by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other services.

under similar conditions. The resulting DMI estimates obtained were slightly below those estimated from the NRC (2001) equation. We calculated pasture intake by subtracting the reported intake of concentrate and forage supplements from the total DMI estimates. Sampling and sample analysis were as in Trial 1. Data were analyzed by regression (Freund and Littell, 1991).

RESULTS AND DISCUSSION

Trial 1

Mean SR maintained in paddocks grazed by lactating cows was 4.6 cows per hectare with only minimal variation observed throughout the experimental period. Mean values for HM and PA were higher in summer than in fall and winter (Table 1). In summer, there was approximately 29% more pasture DM available than during fall and winter seasons. The PA in winter was only 43.3% of that in summer. Regression analysis indicated a significant negative quadratic relationship between week (1 to 32) of harvest and HM ($P < 0.05$; $R^2 = 0.65$), and a weaker ($P < 0.05$; $R^2 = 0.47$) but significant linear relationship between week of harvest and PA. These relationships reflect a decline in pasture availability from that in the wetter and warmer summer to that of the cooler and drier winter season. The reduction in pasture HM is probably due to temperature and sunlight differences between seasons (Vicente Chandler et al., 1983) and to less rainfall during fall and winter.

The increase in pasture production observed during summer should have had implications in the pasture and grazing management practices at the farm. Adjustments in the fertilizer application in the different seasons should be made to allow for the expected response to fertilizer, lower in fall and winter than in spring and summer. Similarly, the overall pasture management should consider the greater production of pasture DM during summer and adjust SR accordingly to maximize the amount of pasture harvested. The farm evaluated and most of the other farms on the Island with similar grazing management do not take into

TABLE 1.—*Mean values (on dry basis) of herbage mass (HM) and pasture allowance (PA) as influenced by season of the year on a commercial dairy farm.*

Season	N	HM (kg/ha)	PA (kg/cow)
July-Sept (summer)	4	2,767	48.7
Oct-Nov (fall)	3	1,911	33.5
Dec-Feb (winter)	3	2,032	21.1

account these seasonal effects on pasture herbage production, and they generally maintain the same SR and rate of fertilizer application throughout the year.

Table 2 presents chemical composition of the supplemental alfalfa hay and concentrate feeds offered at the cooperating commercial dairy farm (Experiment 1). These results represent averages of ten individual samples throughout the experimental period. The chemical composition of the supplemental feeds did not vary appreciably among samples. Thus, a single value was used to represent their chemical composition throughout the seven-month experimental period. Table 3 shows the chemical composition of the grass pasture as it changed throughout the seasons of the year. These values represent averages of at least three samples per season.

Season influenced pasture composition in three main components: crude protein (CP), neutral detergent fiber (NDF), and net energy for lactation (NE_L). Crude protein was highest in fall and then decreased somewhat in winter and was lowest in summer. The NDF content of consumed pasture herbage showed a considerable decline from summer to fall and a further smaller decline in winter. This decline in fiber concentration was reflected in a corresponding increase in the estimated energy value of the grass pasture in fall and winter. Thus, the quality potential of the pasture herbage appears to be highest in winter and higher in fall than summer. However, as stated previously this higher nutritive value in winter coincides with a decline in pasture availability relative to PA in summer. Mineral composition, except for sodium, did not appear to be different among seasons in the grass pasture. Sodium concentration showed a tendency to increase in winter. A

TABLE 2.—*Chemical composition (on dry basis) of alfalfa hay and dairy (DC) and high fiber (HFC) concentrates fed during the experimental period on the cooperating farm.*

Component	Alfalfa	DC	HFC
N	10.00	10.00	10.00
Crude Protein, %	19.20	20.10	21.30
ADF, %	36.30	7.10	11.90
NDF, %	47.90	18.80	28.00
TDN, %	57.00	79.70	81.50
NE_L, Mcal/kg	1.25	1.87	1.98
Calcium, %	1.68	1.34	1.34
Phosphorus, %	0.32	0.65	0.83
Magnesium, %	0.27	0.32	0.43
Potassium, %	2.58	1.16	0.24
Sodium, %	0.10	0.23	0.24

TABLE 3.—*Chemical composition (on dry basis) of tropical grass pasture consumed by lactating cows during summer, fall and winter.*

Component	Summer	Fall	Winter
N	4.00	3.00	3.00
Crude Protein, %	16.90	22.00	18.70
ADF, %	34.10	31.80	33.70
NDF, %	74.00	64.60	62.00
TDN, %	59.00	61.00	61.00
NE_L, Mcal/kg	0.88	1.14	1.21
Calcium, %	0.61	0.64	0.56
Phosphorus, %	0.41	0.48	0.43
Magnesium, %	0.17	0.17	0.17
Potassium, %	2.43	2.57	2.94
Sodium, %	0.04	0.04	0.14

possible explanation could be an increase in the intensity of wind currents during winter; these winds could deposit sea-salt on the pastures.

Intake of DM from supplemental alfalfa hay and commercial dairy concentrates did not change appreciably throughout the experimental period and was assumed constant over the three seasons evaluated (Table 4). Only estimated pasture intake was influenced by season. Intake of pasture DM increased by about 26.6% from summer to winter. This increase resulted in an overall 10.2% increase in total DMI over the same period of time. The increased pasture intake occurred despite an observed trend for lower HM and PA in winter. The increased intake could be the result of higher nutritive value of the pasture harvested during winter and the fact that nutrient needs of lactating cows were higher during winter because of their being in an earlier stage of lactation [fewer average days in milk (DIM); Table 5] than during summer and fall. These results suggest that PA, even at the lowest level re-

TABLE 4.—*Estimated intake of dry matter (DM) from supplements and pasture herbage during the three seasons evaluated.*

Component	Summer	Fall	Winter
Dry matter intake, kg/d			
Alfalfa hay	1.7	1.7	1.7
Dairy concentrate	6.8	6.8	6.8
High-fiber concentrate	1.5	1.5	1.5
Grass pasture	6.4	6.6	8.1
Total	16.7	16.9	18.4
F:C ratio[1]	48:52	49:51	53:47

[1]Forage to concentrate ratio.

TABLE 5.—*Means of days in milk, actual milk production and milk composition of cows in the cooperating herd during the experimental period.*

	Summer	Fall	Winter
Days in milk	194	187	160
Milk yield, kg/d	18.70	20.00	23.40
Milk fat, %	3.07	3.05	3.00
Milk protein, %	3.00	2.85	2.80

ported, was not limiting pasture intake under the pasture management and feeding conditions at the dairy farm evaluated. Consistent with the increase in pasture intake, the forage to concentrate ratio (F:C) of the consumed diet was highest in winter.

Herd milk production and composition data are presented in Table 5. As is the norm in local dairy herds, mean DIM declined slightly from summer to fall and from fall to winter (DRMS, 2007). In most local dairy herds the period when the greatest number of cows calve is from October to January. This seasonal pattern of calving is a consequence of the low fertility experienced during the warm summer and fall months whereas the highest conception rate occurs during the cooler months of January to April. The 25% increase in MY observed from summer to winter coincided with increases in pasture and total DMI and with a decline in DIM of the herd. The small decline in milk fat in winter, despite increases in dietary fiber content, can be attributed to the increases in MY and to the fewer DIM of the herd (earlier stage of lactation).

As stated, intake and nutrient composition of the supplemented alfalfa hay and concentrate feeds remained essentially constant throughout the experimental period. Thus, it was assumed that the only change in nutrient composition of the diet among seasons was due to the amount and nutrient composition of the grass pasture consumed. Estimated nutrient composition of the ration consumed by the experimental herd indicates that CP, calcium, and potassium intakes were much in excess of those needed for the level of milk production observed (Table 6). Similarly, phosphorus concentration in the ration averaged nearly 0.54% and was higher than the 0.42% recommended for the herd evaluated (NRC, 2001). This amount would result in excessive P excretion by the cows. Sodium and NE_L intake appeared to have been just adequate to meet the herd's needs according to NRC (2001).

Milk yield of the cooperating herd was predicted on the basis of estimated CP and energy intake and was compared to actual milk production during the three seasons of the year evaluated (Figure 1). Prediction of MY based on estimates of CP intake were 65.2, 59.5 and 57.7% higher than actual MY during summer, fall and winter, respec-

TABLE 6.—*Estimated chemical composition (on dry basis) of the diet consumed by lactating cows during summer, fall, and winter.*

Component	Summer	Fall	Winter
Crude Protein, %	18.20	18.50	19.20
NDF, %	45.30	40.20	41.10
NE_L, Mcal/kg	1.40	1.50	1.50
Calcium, %	1.08	1.08	1.02
Potassium, %	1.69	1.75	1.98
Phosphorus, %	0.56	0.52	0.53
Sodium, %	0.14	0.14	0.18

tively. On the other hand, when estimated energy intake was used, the predicted milk yield coincided with the actual MY for summer and was only 7.5 and 7.3% higher during fall and winter. Energy was thus shown to have been the most limiting nutrient in the diet of the dairy herd evaluated. The evidence suggests that the low dietary NE_L concentration along with the low intake of grass pasture, particularly during summer, limits the productive potential of the lactating herd. This

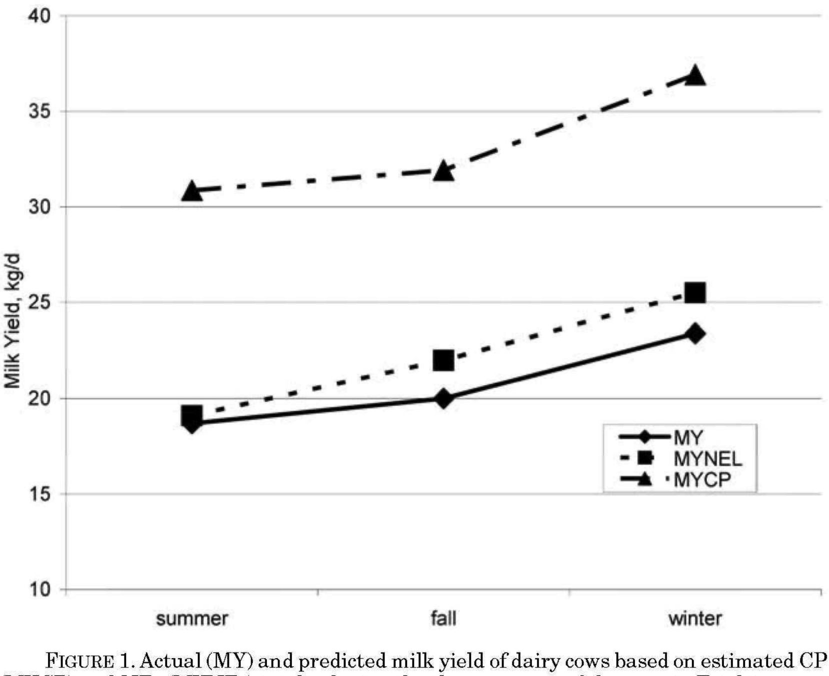

FIGURE 1. Actual (MY) and predicted milk yield of dairy cows based on estimated CP (MYCP) and NE_L ($MYNE_L$) intake during the three seasons of the year in Trial 1.

energy insufficiency in the diet could be expected to occur in other commercial dairy herds with similar grazing management practices.

Trial 2

Data from the 12 herds studied (Table 7) show that their mean average size and daily milk production were similar to average values (185 cows, and 18.1 kg/cow) for the Island (ORIL, 2004). However, detailed analysis of MY data among the individual herds indicated that the highest values were associated with those that had the highest estimated total DMI and which also had the highest pasture consumption. Conversely, herds with the lowest DM and pasture intake were those having lowest average MY. The top five herds averaged 23.6% more MY, 44.2% more pasture intake, 15% more DMI, and 5% less concentrate intake than the rest of the herds evaluated. These percentages indicate the importance of forage in the diet of the lactating cow under our tropical conditions. Dairy herd management should be directed toward maximizing the harvest of pasture of good quality by maintaining adequate grazing conditions.

The values reported for SR at these farms can be considered typical of local commercial dairy herds. Six of the herds evaluated had SRs of less than five; two were between five and 10; and four had SRs greater than 10 cows per hectare. The high SR observed on some of the farms does not appear to be associated with more intense use of feed supplements, particularly of commercial concentrates. The level of concentrates fed, although high, is typical of similar herds on the Island (DRMS, 2007) and is only slightly below the 2:1 milk to concentrate ratio that has traditionally been recommended (Vicente-Chandler et al., 1983). On nine of the 12 farms evaluated, inorganic fertilizer 15-5-10 was applied to pastures at rates below 170 kg of N/ha; however, on all the farms, liquid manure from the waste lagoons was applied to some of their paddocks.

TABLE 7.—*Mean values, in the 12 dairy herds evaluated, of herd size, stocking rate (SR), herbage mass (HM), pasture allowance (PA), concentrate intake (CI), milk yield (MY), and MY to CI ratio (MY:CI).*

	Mean	Range
No. of cows	185	55-335
SR, cow/ha	7.80	1.3-27.5
HM, kg/ha	2,814	1,212-4,068
PA, kg/cow	34.60	9.6-96.0
CI, kg/cow	9.80	7.7-12.9
MY, kg/cow	18.70	14.1-23.6
MY:CI	1.93	1.46-2.4

An increase in the SR resulted in a decline ($P < 0.05$; $R^2 = 0.31$) in HM. Data indicated that for each increase of one AU in SR, HM available before grazing, declined by about 76 kg/ha. This decline could have been influenced by the increased harvest of pasture herbage as SR increased, resulting in shorter residual height and smaller leaf area for subsequent pasture regrowth. In addition, the increase in animal density would likely increase trampling damage to pasture grass roots. As expected, PA was affected ($P < 0.01$) in a negative way by SR. Log transformation of the data indicated a strong ($R^2 = 0.80$) linear relationship; that is, for each unit increase in SR, the daily PA declined by 1.5 kg of DM/cow.

The average PA reported for the 12 farms can be considered more than adequate to allow for maximal pasture herbage intake when liberal supplementation of concentrate is fed (Bargo et al., 2002). However, at seven of the 12 dairies PA values were near or below the minimum recommended. Taken together, these effects on HM and PA would indicate a decline in available herbage because of increased animal competition and pasture deterioration as SR increased. This situation can be expected to increase the dependence of dairy herds on concentrates and other purchased feeds for their rations. However, analysis of the data did not indicate a relationship between SR and concentrate intake (CI), or between CI and MY.

The results of this study suggest that for most of the herds evaluated concentrate supplementation was excessive for their level of milk production. By the same reasoning, on most farms pasture herbage appeared to have been underutilized and could have supported a higher SR, which would have allowed for a more efficient utilization of available pasture.

Results of both trials show the great importance of modifying supplementation and pasture management strategies to compensate for seasonal variability in pasture productivity and intake, thus increasing the efficiency of utilizing nutrients in pasture for MY, and thus of reducing feed costs. More comprehensive studies are needed in order to elaborate pasture management strategies for maximizing forage productivity plus intake potential with dairy cattle well supplemented with concentrates.

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