MILK YIELD AND REPRODUCTIVE PERFORMANCE OF CROSSBRED HOLSTEIN × CRIOLLO LIMONERO COWS

Producción de leche y comportamiento reproductivo de vacas cruzadas Holstein × Criollo Limonero

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ABSTRACT

Records from ½ Criollo Limonero + ½ Holstein (F1) and backcrosses, ¾ Criollo Limonero + ¼ Holstein (R) handled in a Venezuelan humid tropical forest zone were analyzed to compare their productive and reproductive performance. The analyzed variables were: age at first calving (AFC), interval from calving to conception (ICC), calving interval (CI), services per conception (SC), gestation length (GL), calf birth weight (CBW), lactation length (LL), milk at 90 d (M90), total milk yield (TMY), and milk adjusted to 305 d (M305). No statistical differences (P > 0.05) were found between F1 and R for AFC (3.4 ± 0.1 vs 3.2 ± 0.1 years), SC (1.6 ± 0.1 vs 1.7 ± 0.1), GL (both 280d), CBW (both 34 ± 0.6 kg), M90 (919 ± 99 vs 813 ± 105 kg), TMY (2093 ± 176 vs 1964 ± 176 kg) or for M305 (2424 ± 146 vs 2430 ± 151kg), respectively. However, the F1 cows had ICC (258 ± 18 vs 173 ± 22 d; P < 0.004) and CI (577 ± 21 vs 474 ± 25 d; P < 0.001) longer than R, respectively. Year of birth affected (P < 0.05) to AFC, (P < 0.03) to ICC, and (P < 0.01) to CI, M90, TMY, and M305. Environmental effects were found for GL, M90, TMY, M305, and LL. Although no differences between genotypes were found for milk yield, R cows had better reproductive performance than the F1 cows.

Key words: Criollo, Holstein, crossbreeding, reproduction, milk.

RESUMEN

Con el objetivo de comparar el comportamiento productivo y reproductivo, se analizaron los registros de vacas ½ Criollo Limonero + ½ Holstein (F1) y retrocruces ¾ Criollo Limonero + ¼ Holstein (R) manejadas en una zona de bosque húmedo tropical venezolana. Se analizaron las variables edad al primer parto (AFC), intervalo parto-concepción (ICC), intervalo entre partos (CI), servicios por concepción (SC), duración de la gestación (GL), peso al nacer de los becerros (CBW), longitud de lactancia (LL), producción de leche total (TMY), a los 90 días (M90) y ajustada a 305 días (M305). No se hallaron diferencias significativas (P > 0,05) entre F1 y R para AFC (3,4 ± 0,1 vs 3,2 ± 0,1 años), SC (1,6 ± 0,1 vs 1,7 ± 0,1), GL (ambos 280d), CBW (ambos 34 ± 0,6 kg), M90 (919 ± 99 vs 813 ± 105 kg), TMY (2093 ± 176 vs 1964 ± 176 kg) ni M305 (2424 ± 146 vs 2430 ± 151kg), respectivamente. No obstante, las F1 tuvieron ICC (258 ± 18 vs 173 ± 22 d; P < 0,004) e CI (577 ± 21 vs 474 ± 25 d; P < 0,001) más prolongados que las R, respectivamente. El año de nacimiento afectó (P < 0,05) a AFC, (P < 0,03) ICC, y (P < 0,01) a CI, M90, TMY, y M305. Se hallaron efectos climáticos sobre GL, M90, TMY, M305, y LL. Aunque sin diferencias en producción de leche, las R tuvieron mejor desempeño reproductivo.

Palabras clave: Criollo, Holstein, cruzamientos, reproducción, leche.

INTRODUCTION

Milk yield in tropical countries is traditionally deficient. Given the social impact that milk consumption has in human populations [56], tropical countries have consistently imported

Recibido: 17 / 06 / 2005. Aceptado: 14 / 12 / 2005.

animals from temperate zones as a strategy to overcome such deficits. To date, no success has been obtained using this strategy. In Venezuela, genetic improvement of local genotypes such as the Criollo Limonero has not been approached with the appropriate seriousness. Meanwhile, experiences with crossing exotic to tropical genotypes have occurred more frequently, but without proper design and evaluation.

The Criollo cattle of Venezuela have declined in number without valid information of their genetic potential. Other countries, such as Colombia and Costa Rica, have done a better job of evaluating their own criollo breeds. In general, however, there is a lack of scientific information on Criollo cattle across all of Latin America.

Looking for a type of cattle adapted to the region south of Lake Maracaibo, crosses between Criollo Limonero and Holstein were developed in the state of Zulia, Venezuela. Because of a poor survival rate, poor growth rate, and general poor performance, a third group (¾ Holstein + ¼ Criollo Limonero) was considered unadapted and eliminated. The objective of this study was to compare the productive and reproductive performance of F1 (½ Criollo Limonero + ½ Holstein) and backcross (¾ Criollo Limonero + ¼ Holstein) in a hot-humid tropical environment.

MATERIALS AND METHODS

Records from F1 (½ Criollo Limonero + ½ Holstein) and backcrosses (¾ Criollo Limonero + ¼ Holstein) cows housed at Local Station Chama, INIA, Zulia State, Venezuela were analyzed. The Local Station Chama is located in a zone described as a humid tropical forest (e.g., annual rainfall ranged from 1.500 – 1.800 mm, average temperature = 28,4°C, relative humidity = 82% and evaporation = 1.589 mm). The F1 cows were produced by crossing Holstein sires (n = 14) to purebred Criollo Limonero cows, while for backcrosses, Criollo Limonero sires (n = 9) were bred to F1 cows. For statistical purposes, no sire with less than 3 daughters was included in the analyses.

Feeding of animals included: grazing on Guinea grass (*Panicum maximum*), commercial concentrate (2 kg/d), and a mineral mix offered *ad libitum*. Cows were subjected to manual milking without calf at side. Heat detection was performed by visual observations in two 30 min/d sessions (AM-PM). Cows were impregnated by artificial insemination solely. Pregnancy diagnosis was performed by rectal palpation between 45 and 60 d postservice. Cows were dried off 60 d before calving or due to low milk yield (e.g., ≤ 2 L/d). Postpartum voluntary rest period lasted 45 d. Cow body weight was recorded before calving and monthly after calving.

Environmental data (temperature –T°–, relative humidity –Hr–, and radiation) was obtained from the Moralito Station located about 15 min from Chama Station. Using such data, two seasons were established. One of high temperature + moderate humidity (HTº- MH = 27ºC and 66-70% Hr) and another of high temperature + high humidity (HTº-HH = 27-28ºC and 74-83% Hr). The HTº-MH season included January, February, July and August. HTº-HH included March, April, May, June, September, October, November, and December. As a class variables, predominant season (e.g., HT°- MH or HT°- HH) during the last third of gestation and during first third of lactation were then created. In order to estimate the level of radiation during the last third of gestation, records corresponding to the last third of gestation for each cow were averaged and introduced to the data as a random variable. Data on local climate is shown in TABLE I.

The dependent variables analyzed were: age at first calving (AFC), interval from calving to conception (ICC), calving interval (CI), services per conception (SC), gestation length (GL), calf birth weight (CBW), milk yield at 90 d (M90), total milk yield (TMY), milk adjusted to 305 d (M305), and lactation length (LL).

The statistical analysis of dependent variables to evaluate reproductive efficiency (e.g., AFC, ICC, CI, SC) comprised models that included: genotype, year of birth, sire and sire within genotype for AFC. Models for ICC, CI, and SC included genotype, year of birth, parity, age at calving, year of calving, predominant season during last third of gestation, predominant season during first third of lactation, calf birth weight, cow´s postpartum body weight, milk yield at 90 d, and total milk yield.

The statistical analysis of dependent variables to evaluate milk yield (e.g., M90, TMY, M305, LL) comprised models that included: genotype, year of birth, parity, age at first calving, year of calving, predominant season during last third of gestation, predominant season during first third of lactation,

TABLE I

MORALITO CLIMATOLOGICAL STATION. MEANS FOR TEMPERATURE (ºC) AND RELATIVE HUMIDITY (Hr). AVERAGE LAST TEN YEARS / ESTACIÓN CLIMATOLÓGICA MORALITO. MEDIAS PARA TEMPERATURA (ºC), HUMEDAD RELATIVA (Hr) Y RADIACIÓN SOLAR (RS). PROMEDIO ÚLTIMOS DIEZ AÑOS

Variable	Meses											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T°C	27	27	27	27	28	28	26	27	27	28	28	28
Hr %	67	66	74	74	75	71	66	67	83	83	82	82
RSCal/cm	390	350	386	346	360	370	363	391	379	361	320	294

Fuente: Estación Moralito. MARN. Zulia, Venezuela.

level of radiation during last third of gestation, calf birth weight, cow´s postpartum body weight, interval calving to conception, and sire within genotype. For statistical analyses of TMY and M305, M90 was added to the model.

Variables such as GL and CBW were analyzed with statistical models that included: genotype, parity, age at calving, predominant season during last third of gestation, level of radiation during last third of gestation, calf birth weight, calf sex, and sire within genotype for GL. Meanwhile, for CBW, statistical models included: genotype, parity, year of birth, year of calving, predominant season during last third of gestation, level of radiation during last third of gestation, calf sex, gestation length and sire within genotype.

For all cases, the statistical procedure was ANOVA using PROC GLM [51]. Pearson correlations were obtained by using PROC CORR [51]. The level of statistical significance was pre-established at $P < 0.05$. Meanwhile, P-values above $P < 0.05$ and below $P < 0.10$ were considered tendencies.

RESULTS AND DISCUSSION

Age at first calving (AFC)

Age at first calving did not differ ($P > 0.05$) between ½ Holstein + ½ Criollo Limonero (3.4 ± 0.1 years) and ¾ Criollo Limonero + ¼ Holstein (3.2 ± 0.1 years). However, AFC varied ($P < 0.05$) by year of birth from 2.8 ± 0.2 to 3.7 ± 0.2 years between the best and the worst years. Moreover, AFC was also influenced ($P < 0.05$) by sire. In general, AFC varied between 2.6 ± 0.2 and 4.7 ± 0.5 years by sire. Among cows sired by Holstein bulls, AFC varied between 2.6 ± 0.2 and 4.7 ± 0.5 years. Meanwhile, among cows sired by Criollo Limonero bulls, AFC varied between 2.8 ± 0.5 and 4.6 ± 0.5 years.

The AFC is important because, profit potential begins only when a heifer calves and start to produce milk. Thus, when AFC is longer than the productive life, the cow does not generate profits. In intensive dairy operations, any time a heifer goes longer than 30 m for AFC, she becomes unprofitable [43].

The AFC has been controversial in other studies comparing dairy crosses with Criollo breeds [9, 10]. In our study, the lack of a statistical difference for AFC between genotypes could imply that environmental effects and management deficiencies negatively affected the F1 animals to a larger extent than they did to the backcrosses. Especially in tropical zones, there is overwhelming evidence that exotic breeds are more susceptible to environmental stress and limited nutritional availability than native breeds.

The effect of year of birth on AFC is not rare. As with previous reports with Criollo Limonero and Romosinuano cows [31, 44], year of birth influenced AFC in this study. Variations in AFC due to year of birth have been routinely explained by environmental, management and personnel differences occurring in farms across years. Nevertheless, there is a need to evaluate the impact of these adverse conditions of a given year on the productive life of cows. It has been reported in sheep, that severe under nutrition during gestation and growing periods may lead to delayed puberty [14].

A sire effect on AFC was reported in Holstein [43] and crossbred tropical Holstein heifers [59]. However, there are discrepancies with other reports using Criollo Limonero [31] and Romosinuano [44]. On the other hand, although weight at 2 ($\hat{h}^2$ = 0.71), 3 ($\hat{h}^2$ = 0.61) and 4 years old ($\hat{h}^2$ = 0.68) possess a high heritability in other breeds [1], the opposite has been observed [39] with the age at first service and first calving ($\hat{h}^2$ = 0.03-0.08).

The wide variability observed on AFC according to sire within breed is of interest as a similar difference does not occur between the Holstein and Criollo Limonero breeds. This leads us to speculate that, once management aspects (e.g., nutrition and health) are met, it may be possible to reduce AFC through sire selection.

Interval from calving to conception (ICC) and calving interval (CI)

As shown in TABLE II, ½ Holstein + ½ Criollo Limonero cows had longer ICC ($P < 0.004$) and CI ($P < 0.001$) than ¾ Criollo Limonero + ¼ Holstein cows. Variations due to year of birth were observed for ICC (258 ± 33 to 138 ± 41 d; $P < 0.03$) and CI (590 ± 40 to 434 ± 35 d; $P < 0.01$). Prolonged ICC and CI were observed when age to first calving ($P < 0.02$) and total milk yield ($P < 0.0002$) were increased. Moderate correlations were found between ICC and CI with total milk yield (r = 0.33 and r = 0.26; $P < 0.0001$, respectively), adjusted milk 305 d (r = 0.21 and r = 0.22; $P < 0.004$, respectively) and lactation length (r = 0.39 and r = 0.35; $P < 0.0001$, respectively).

A reduction of the ICC and CI in parallel with an increase of Criollo blood was also observed in Romosinuano cattle [9] and may be explained by genotype × environment interactions. The predominantly high temperature and humidity, swampy soils and lack of an adequate management could represent strong disadvantages for the ½ Holstein + ½ Criollo Limonero as compared with the ¾ Criollo Limonero + ¼ Holstein. Because of the greater composition of Criollo blood in the backcrosses, these cows might exhibit stronger resistance than the ½ Holstein + ½ Criollo Limonero. It should be considered that the Criollo Limonero cattle evolved in these environmental conditions over the last 4 centuries.

As with the present study, the effect of year of birth on ICC and CI has been previously reported [9]. Analyzing the year effect in detail may lead to critical implications because it suggests that the level of pre- and postweaning under nutrition may trigger repercussions during an animal´s productive lifespan [14, 26, 46, 47]. Likewise, subsequent under nutrition during key stages may alter the circulating levels of glucose, insulin, IGF-I and IGFBP [30, 35, 60]. Distortions in the normal circulating levels of these hormones may negatively affect steroidogenesis,

TABLE II
INTERVAL CALVING TO CONCEPTION (ICC) AND CALVING INTERVAL (CI) IN CROSSBRED HOLSTEIN × CRIOLLO LIMONERO COWS. LEAST SQUARE MEANS ± STANDARD ERROR (LSM ± SE) / INTERVALOS PARTO CONCEPCIÓN (ICC) E INTERVALO ENTRE PARTOS (CI) EN VACAS CRUZADAS HOLSTEIN × CRIOLLO LIMONERO. MEDIAS CUADRÁTICAS ± ERROR ESTÁNDAR

Genotype	ICC		CI	
	N	LSM ± EE (d)	N	LSM ± EE (d)
(½ H ½ + CL)	157	258 ± 18[a]	171	577 ± 21[c]
(¾ CL + ¼ HLS)	56	173 ± 22[b]	63	474 ± 25[d]
Criollo Dominicano				490*
Reyna (Nicaragua)				387*
Criollo Saavedreño (Bolivia)				404*
Criollo Costeño con Cuernos (Colombia)				475*
BON (Colombia)				525*

[(a,b)] within a column and different superscript differ (P < 0.004). [(c,d)] within a column and different superscript differ (P < 0.001).
* Modified from Tewolde and Van Dijk (1993).

cell proliferation, aromatase activity, folliculogenesis, ovulation, implantation and development [62]. The implications of the under nutrition related to the so-called effects of year and season are relevant but seldom evaluated in tropical zones.

The effect of milk yield on ICC and CI has been previously reported in Criollo cattle [10]. Especially under deficient nutritional levels, an increase of milk yield may lead to energy imbalances compromising the reproductive function [38]. Probably, the correlations between lactation length and ICC (r = 0.39; P < 0.001) and CI (r = 0.35; P < 0.001) found in this study are associated with this issue. Prolonged CI due to an increased milk yield was observed in Romosinuano cows [10].

Services per conception (SC)

No difference (P > 0.05) was found for SC between ½ Holstein + ½ Criollo Limonero (1.6 ± 0.1) and ¾ Criollo Limonero + ¼ Holstein (1.7 ± 0.1). Age at first calving influenced (P < 0.001) and had a moderate correlation (r = 0.20; P < 0.005) with SC. Year of calving tended (P < 0.10) to affect SC.

In general, the SC observed between the genotypes under study may be considered satisfactory. However, studies in Criollo and Criollo × Jersey [9, 10] found that heritability ($\hat{h}^2$ = 0.07 ± 0.03) and repeatability (r = 0.02 ± 0.05) of SC are low. Therefore, these authors concluded that until third service, fertility is associated more with environmental and management aspects.

Gestation length (GL)

The GL did not differ (P > 0.05) among ½ Holstein + ½ Criollo Limonero (280 ± 0.4 days) and ¾ Criollo Limonero + ¼ Holstein (280 ± 1 days) cows. However, GL was influenced by the level of solar radiation across the last third of gestation (P < 0.03).

The GL is a species specific parameter. Therefore, wide variations of GL may only indicate casualties or pathological and environmental abnormalities. Permanently increased solar radiation and humidity are potent stressors [3] leading to release of ACTH and cortisol [18]. The ACTH and cortisol are hormones which trigger parturition [55]. Moreover, during the last third of gestation, heat stress negatively affects the placental function [27]. Others have found decreased concentrations of circulating progesterone due to chronic or prolonged heat stress [61].

Calf birth weight (CBW)

As shown in TABLE III, CBW did not differ (P > 0.05) between calves out of ½ Holstein + ½ Criollo Limonero and ¾ Criollo Limonero + ¼ Holstein cows. Male calves tended (P < 0.09) to be heavier than female calves. The CBW increased with parity (P < 0.001) and varied (P < 0.02) with year of calving (maximum and minimum of 36 ± 1 to 32 ± 1 kg, respectively).

Both, a high Criollo component (50-75%) and the effect of heat stress on the placenta function [27] are likely reasons to explain the lack of differences in CBW between genotypes. With regard to the effect of calf gender and parity on CBW, these have been routinely reported. Male calves are heavier than females due to a slightly prolonged gestation [48], greater exposure to androgens [5] and larger body measurements [32] compared to female calves. Meanwhile, the effect of parity occurs because with the increased age, the nutrient partitioning between dam and fetus becomes more favorable for the fetus in older dams [29].

Milk yield

Milk yield did not differ (P > 0.05) between genotypes. However, there were differences (P < 0.05) in total milk yield (TMY) and milk adjusted to 305 d (M305) across parity (TABLE IV). Likewise, there were variations in milk yield at 90 d (M90) and TMY (P < 0.001) according to sire within breed.

TABLE III

EFFECT OF DAM GENOTYPE, GENDER AND PARITY ON CALF BIRTH WEIGHT (CBW). LEAST SQUARE MEANS ± STANDARD ERROR (LSM ± SE) / EFECTO DEL GENOTIPO, SEXO DEL BECERRO Y NÚMERO DE PARTOS SOBRE EL PESO AL NACER. MEDIAS CUADRÁTICAS ± ERROR ESTÁNDAR

	CBW	
	N	LSM ± SE (kg)
Dam genotype		
F1 (½ H ½ + CL)	268	34 ± 0.7^{ns}
F2 (¾ CL + ¼ H)	89	34 ± 0.6^{ns}
Calf gender		
Female	175	33 ± 0.6^{a}
Male	182	34 ± 0.6^{b}
Parity		
1	116	30 ± 0.5^{c}
2	88	32 ± 0.4^{df}
3	65	32 ± 0.4^{df}
4	40	32 ± 0.6^{df}
5	30	33 ± 0.7^{df}
6	12	35 ± 1.0^{dg}

$^{(a,b)}$ within a column and different superscript differ (P < 0.09).
$^{(a,c)}$ within a column and different superscript differ (P < 0.02).
$^{(d,e)}$ within a column and different superscript differ (P < 0.005).

Whenever the sire was Criollo Limonero, M90 varied from 1292 ± 180 to 714 ± 97 kg and TMY varied from 3403 ± 464 to 1280 ± 285 kg). Nevertheless, when the sire was Holstein, no statistical difference (P > 0.05) was observed in M90 (1057 ± 42 and 786 ± 234 kg) but there was a difference in TMY (3412 ± 387 and 1124 ± 590 kg). No differences were observed on M305 when cows sired by Criollo Limonero (2922 ± 350 and 2438 ± 334 kg) and Holstein (2752 ± 273 and 2095 ± 333 kg) bulls were compared.

In addition, M90 influenced (P < 0.0001) and was positively correlated with TMY and M305 (r = 0.32 and r = 0.26, respectively; P < 0.001). In the ½ Holstein + ½ Criollo Limonero, M90 represented 44% of TMY and 38% of M305. Meanwhile in the ¾ Criollo Limonero + ¼ Holstein, M90 represented 41% and 33% of TMY and M305, respectively.

As shown in TABLE V, significant variations in M90, TMY, and M305 were associated with year of birth. Likewise, solar radiation (P < 0.01) and the combined effect of high temperature-humidity during the last third of gestation tended (P < 0.09) to exert a detrimental effect on M90, TMY and M305. A reduced (P < 0.05) M90 was observed in those cows with prolonged age at first calving. Moderate correlations were found between ICC and CI with TMY (r = 0.33 and 0.26; P < 0.001, respectively) and with M305 (r = 0.21 and 0.22; P < 0.004, respectively). These correlations point out the occurrence of re-

TABLE IV

MILK YIELD IN CROSSBRED HOLSTEIN × CRIOLLO LIMONERO COWS. LEAST SQUARE MEANS ± STANDARD ERROR (LSM ± SE) / PRODUCCIÓN LECHERA EN VACAS CRUZADAS HOLSTEIN × CRIOLLO LIMONERO. MEDIAS CUADRÁTICAS ± ERROR ESTÁNDAR

	Milk Yield at 90d (kg)	
	N	LSM ± EE (d)
Genotype		
½ H + ½ CL	223	919 ± 99^{ns}
¾ CL + ¼ H	80	813 ± 105^{ns}
Parity		
1	98	910 ± 74^{ns}
2	79	908 ± 61^{ns}
3	59	835 ± 73^{ns}
4	34	889 ± 98^{ns}
5	23	809 ± 130^{ns}
	Total Milk (kg)	
	N	LSM ± EE (d)
Genotype		
½ H ½ + CL	225	2093 ± 176^{ns}
¾ CL + ¼ H	84	1964 ± 176^{ns}
Parity		
1	98	2568 ± 114^{a}
2	79	2453 ± 120^{ab}
3	59	2448 ± 133^{ab}
4	39	2187 ± 162^{b}
5	24	1979 ± 205^{bc}
	Milk Adjusted 305d (kg)	
	N	LSM ± EE (d)
Genotype		
(½ H ½ + CL)	151	2424 ± 146^{ns}
(¾ CL + ¼ Hls)	31	2430 ± 151^{ns}
Parity		
1	77	2723 ± 66^{d}
2	51	2440 ± 77^{e}
3	36	2601 ± 91de
4	13	2438 ± 146^{fe}
5	4	2301 ± 267de

$^{(a,b)}$ within a column and different superscript differ (P < 0.05).
$^{(b,c)}$ within a column and different superscript differ (P < 0.04).
$^{(d,c)}$ within a column and different superscript differ (P < 0.04).
$^{(d,f)}$ within a column and different superscript tended to differ (P < 0.07).

TABLE V

MILK AT 90 DAYS (M90), TOTAL MILK YIELD (TMY), AND MILK ADJUSTED TO 305 DAYS (M305) BY YEAR OF BIRTH, AND PREDOMINANT SEASON DURING LAST THIRD OF GESTATION IN CROSSBRED CRIOLLO LIMONERO × HOLSTEIN COWS. LEAST SQUARE MEANS ± STANDARD ERROR (LSM ± SE) / PRODUCCIÓN DE LECHE A 90 D, PRODUCCIÓN DE LECHE TOTAL Y AJUSTADA A 305 D POR EL AÑO DE NACIMIENTO Y LA ESTACIÓN PREDOMINANTE DURANTE EL ULTIMO TERCIO DE GESTACIÓN EN VACAS CRUZADAS HOLSTEIN × CRIOLLO LIMONERO. MEDIAS CUADRÁTICAS ± ERROR ESTÁNDAR

	N	M90 (kg)	N	TMY (kg)	N	M305 (kg)
Year						
1984	42	1180 ± 108[a]	45	3008 ± 200[e]	40	2946 ± 139[h]
1985	26	1128 ± 117[ac]	20	2466 ± 232[f]	25	2589 ± 175[ij]
1986	17	1037 ± 136[acd]	17	2440 ± 269[f]	16	2662 ± 209[hjl]
1987	63	1007 ± 92[bc]	60	2414 ± 175[f]	43	2485 ± 143[ijl]
1988	43	858 ± 102[bd]	42	1824 ± 202[g]	30	2018 ± 162[ikm]
1989	24	854 ± 120[bd]	24	1656 ± 238[g]	19	1933 ± 197[ikm]
1990	24	893 ± 105[bd]	52	1898 ± 191[g]	29	2377 ± 160[ijl]
1991	53	1187 ± 139[ac]	17	1192 ± 271[g]	7	1642 ± 306[ikm]
1992	16	812 ± 139[bd]	16	1237 ± 275[g]	-	-
Season						
H-H	112	876 ± 54 [*]	71	1728 ± 112[*]	71	2116 ± 126[*]
H-MH	191	981 ± 36 [**]	240	1994 ± 126[**]	119	2374 ± 110[**]

[(a,b), (c,d), (e,f)] within a column and different superscript differ ($P < 0.01$). [(h,i)] within a column and different superscript differ ($P < 0.05$).
[(j,k)] within a column and different superscript differ ($P < 0.02$). [(l,m)] within a column and different superscript differ ($P < 0.003$).
(*,**) within a column and different superscript tended to differ ($P < 0.09$). H-H: hot and humid. H-MH: hot and moderate humidity.

productive problems which prolonged the lactation with a concomitant increase in TMY.

The lack of differences between genotypes in M90, TMY, and M305 does not agree with other reports comparing tropical breeds and their crosses with temperate breeds [2, 7, 19]. Due to the harsh environmental conditions at the Chama Station (e.g., high temperature, high humidity, poor drained soils, parasites, sparse forrage due to high stocking rates), interactions between genotype and environment could be occurring. In such a case, the adverse environment may have affected the ½ Holstein + ½ Criollo Limonero to a greater degree.

The results of this work suggest that, in tropical regions with extreme environmental conditions, the increase of temperate *Bos taurus* breeding leads to a similar or inferior productive performance when compared to tropical breeds. On the other hand, the milk production of cows in this study was better than that reported [57] for other criollo genotypes such as Criollo Dominicano (1600 kg/lact), Reyna from Nicaragua (1363 kg/lact), Criollo Saavedreño from Bolivia (1165 kg/lact), Criollo Costeño con Cuernos (996 kg/lact), and BON from Colombia (454 kg/lact).

The effect of parity on milk yield in Criollo cattle has been reported [10, 12, 13, 31]. As cows reach their adult weight, their nutritional requirements for growth are decreased and the mammary tissue reaches its greatest development [23, 54]. If nutritional management is appropriate, such mammary development leads to concomitant increases of milk yield until third lactation [12, 25]. However, contrary to the previous statements, cows in the present study showed a decreased milk yield as parity increased. In contrast, previous studies with Criollo Limonero [13, 45] and Carora cows [11] did not find an effect of parity on milk yield or differences only existed between cows at their first versus cows with 2 or more lactations, respectively. Decreased milk yield concomitant with increased parity, or the lack of effect of parity on milk yield are illogical findings pointing out likely nutritional mismanagement and a deteriorating environment.

The effect of sire on milk yield is not rare [31, 59]. The wide variation in M90, TMY, and M305 among sires in our study suggests opportunities for selection. However, since a similar finding occurred with cows sired by Holstein bulls, and the small number of daughters included per bull, one should be cautious in the interpretation of these results.

With regard to the effect of heat stress during the last third of gestation, it may cause acute and prolonged negative effects on lactation [58]. Reducing feed intake is a paramount mechanism used by a heat stressed ruminant to decrease heat load [6]. Reducing feed intake during the last third of gestation leads to a reduction of body reserves which are needed later in lactation. The association of high temperature and high humidity was found responsible for important variations on milk yield in Holstein and Jersey cows [53]. Heat stress during 60 d prepartum had a detrimental effect on milk yield and fat during the first and second lactation [41]. Moreover, the heat stress during gestation may reduce development and function of the pla-

TABLE VI
EFFECT OF GENOTYPE, YEAR OF CALVING AND PREDOMINANT SEASON DURING THE LAST THIRD OF GESTATION ON LACTATION LENGTH IN CROSSBRED CRIOLLO LIMONERO × HOLSTEIN COWS. LEAST SQUARE MEANS ± STANDARD ERROR (LSM ± SE) / EFECTO DEL GENOTIPO, AÑO DE NACIMIENTO Y ESTACIÓN PREDOMINANTE DURANTE EL ÚLTIMO TERCIO DE GESTACIÓN SOBRE LA DURACIÓN DE LA LACTANCIA. MEDIAS CUADRÁTICAS ± ERROR ESTÁNDAR

	Lactation Length	
	N	LSM ± SE (kg)
Genotype		
½ H + ½ CL	225	320 ± 14[a]
¾ CL + ¼ H	81	277 ± 17[b]
Year Calving		
87	11	325 ± 38[c]
88	11	304 ± 37[cf]
89	27	352 ± 25[cfh]
90	27	385 ± 24[cgh]
91	21	368 ± 26[cfh]
92	48	333 ± 19[cfh]
93	32	295 ± 21[cfh]
94	34	285 ± 21[cfi]
95	28	269 ± 22[cfi]
96	30	231 ± 22[dfi]
97	12	221 ± 33[dfi]
98	16	284 ± 29[cfi]
Pred. Season		
Hot-high humidity	237	284 ± 12[j]
Hot-moderate humidity	69	314 ± 16[e]

Pred. Season N LSM ± SE (kg). Hot-high humidity237 284 ± 12[j]. Hot-moderate humidity 69 314 ± 16[e].

[(a,b)] within a column and different superscript differ ($P < 0.01$).
[(e,d)] within a column and different superscript differ ($P < 0.04$).
[(f,g)] within a column and different superscript differ ($P < 0.03$).
[(h,i)] within a column and different superscript differ ($P < 0.05$).
[(j,e)] within a column and different superscript differ ($P < 0.05$).

centa [27] which could negatively affect mammary development and subsequent milk yield [16, 20].

Given the environmental conditions experienced by the animals of this study (e.g., high temperature and humidity, swampy soils, sparse forage due to high stocking rates, etc), the effects of year of birth and calving on milk yield are understandable. Under such deteriorated conditions, which resulted in poor management of nutrition and poor health during growth and development, chronic and detrimental effects on productive life are expected.

The effect of year and parity on milk yield was previously discussed in Criollo, Holstein and Jersey cows [15, 28, 31, 43, 49]. However, chronic effects of poor nutrition on mammary gland development should not be discarded. The effect of poor nutrition and associated endocrine events (e.g., GH, prolactin, insulin, IGF) on mammary growth and development of the growing heifer have been discussed [4, 17, 28, 33, 42, 50, 52].

With reference to the relationship between nutritional stage and mammary development, there is a difference between approaches of tropical underdeveloped and temperate developed countries. Although with similar consequence (decreased milk yield), in temperate developed countries, the decrease on milk yield occurs because of the reduced age at which first calving takes place due to the high nutritional plane [21, 37, 40]. On the contrary, in tropical zones, other studies [8, 22, 33, 34, 36, 50, 52] suggest that mammary development may be limited by under nutrition and prolonged age to first calving (as observed in our study). More recently, a study with Fleckvieh cattle suggests that a late first calving may exert detrimental effect on the productive performance of offsprings [24]. Unfortunately, in tropical zones, the availability of this type of research is too scarce but urgent.

Lactation length (LL)

As shown in TABLE VI, LL was longer ($P < 0.01$) in ½ Holstein + ½ Criollo Limonero than ¾ Criollo Limonero + ¼ Holstein. Likewise, LL was longer in those cows in which high temperature and moderate humidity prevailed during the last third of gestation. There was also a variation in LL due to year of calving.

The longer LL in ½ Holstein + ½ Criollo Limonero compared to ¾ Criollo Limonero + ¼ Holstein is likely a consequence of reproductive problems as evidenced from the correlations between ICC and CI with total milk yield. Previous studies with Criollo Limonero cows reported lactations between 274 and 288 d. However, in that study, variations in LL due to the effects of year and parity went as far as 358 d [13, 31, 45].

CONCLUSIONS

Under the prevalent conditions at the Estación Local Chama, no differences were found in milk yield between F1 (½ Holstein + ½ Criollo Limonero) and backcrosses (¾ Criollo Limonero + ¼ Holstein). However, in reproductive terms, the backcrosses performed better than the F1 (e.g., shorter ICC and CI). Strong environmental effects leading to a reduced milk yield were present during the last third of gestation. Other environmentally-related variables such as year of birth and year of calving suggest the possibility of chronic effects due to undernutrition on milk production and reproduction.

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