Crossbreeding Cattle for Milk Production in the Tropics: Effects of Genetic and Environmental Factors on the Performance of Improved Genotypes on the Cameroon Western High Plateau*

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■ RESSOURCES ANIMALES

Key words

Cattle – Crossbreeding – Milk production – Yield factor – Tropics – Cameroon.

Summary

Three hundred and sixty-four records on dairy production obtained from 540 lactations of 145 cows that calved between 1974 and 1994 at the Bambui Centre of Agricultural Research for Development in the western highlands of Cameroon were analyzed for effects of genotype and environment on milk production and reproduction traits. Cow genotypes were Holstein-Friesian (H), Jersey (J), Holstein-Red Fulani F_1 (H_1RF_1), Holstein-Gudali F_1 (H_1G_1), Jersey-White Fulani F_1 (J_1WF_1) and Jersey-White Fulani backcrosses (J_3WF_1, J_7WF_1). Effects of genotype, season and year of calving, parity and age at first calving (AFC) were analyzed. The lactation milk yield (MYLD), lactation length (LL), annualized milk yield (AMP), calving interval (CI) and dry period (DP) were also analyzed. F_1 crosses (H_1G_1, J_1WF_1, H_1RF_1) and backcrosses (J_3WF_1, J_7WF_1) were compared. H_1G_1 were superior to H_1RF_1, J_1WF_1, and J_3WF_1 with regard to MYLD, AMP, LL, CI, and DP. For AFC, H_1G_1 were superior to J_1WF_1, J_3WF_1, J_7WF_1, but inferior to H_1RF_1. Jersey backcrosses were superior to Jersey F_1. Milk production of F_1 crosses varied from 2.6 times (J_1WF_1 vs WF) to 4.3 times (H_1RF_1 vs RF) the yield of local breeds. Among F_1 crosses, H_1G_1 were the best.

■ INTRODUCTION

Milk is no doubt one of the most important sources of protein in human nutrition in the tropics. In Cameroon, for example, consumption was estimated per capita at 10 kg (11, 45), for an annual domestic milk production estimated at 5.1 kg per inhabitant (28). The production deficit is compensated with dairy product imports. In 1992, milk imports were 11,480 tons for a total cost of 10 billion CFA francs (43). In 1995, the national milk production was estimated at 100,000 tons, and dairy imports were 30,260 tons for a total cost of 24 billion CFA francs (27). In 1999, powdered milk and concentrated milk imports were estimated for the first nine months to be above 14,000 tons, for a total of 12 billion CFA francs (26).

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For decades, milk production in tropical Africa has been mostly ensured by zebu breeds (*Bos indicus*) (8). In Cameroon, local zebu breeds are Red Fulani (RF) or Mbororo, White Fulani (WF) or Aku, and Gudali (G) also called Adamawa or Ngaoundere. Their daily production ranges roughly from one to two liters per cow, with a lactation length of 140 to 180 days (13). These non-specialized breeds are used commonly as dual-purpose animals, providing milk and meat. To improve the low productivity and production, high performance exotic dairy cattle (*Bos taurus*) breeds, Holstein-Friesian (H) and Jersey (J) from the USA, and Montbeliard and Brown Swiss from France, were introduced in the early seventies (17, 24, 29, 40, 42). Thus, improved hybrids (exotic x local) were produced at Wakwa in the northern highlands, also known as Adamawa Highlands, and at Bambui in the western highlands, also known as Bamenda Highlands. Research efforts were intensified with the aim of identifying productive and adapted genotypes for the enhancement of dairy production in Cameroon (17, 29).

The economic importance of lactation and reproductive traits in dairy production cannot be over emphasized. Both the environment and heredity are known to cause phenotypic variations in these quantitative traits. Reduction of environmental variance is expected to leave a greater portion of the residual variance to heredity and thereby to increase the prediction accuracy of the superiority of the individual. Hence, knowledge of environmental factors is important for genetic improvement of dairy cattle.

The design of efficient mating schemes for such genetic improvement requires knowledge not only of breed differences but also of their heterotic and recombination effects (8, 18). Limited studies have compared the performance of crossbred genotypes with at least two *Bos taurus* breeds under similar production conditions (14, 34, 37, 40, 44). Furthermore, most of the crossbreeding evaluation studies in West Africa have been limited to the White Fulani as indigenous cow breed (5, 10). Gudali crosses with exotic dairy breeds have recently been evaluated (40) for their dairy potential in the northern highlands of Cameroon. A similar evaluation to complete the study is not yet available for the western highlands of Cameroon. Furthermore, no study has been carried out to evaluate crosses of Red Fulani with exotic dairy breeds. Similarly, no study has been carried out to compare Gudali and Red Fulani (both originating from the subregion) for their crossbreeding potentials for milk production.

Data generated from 1974 to 1983 were analyzed but they mainly presented descriptive statistics (24). The effects of calving season and production parameters on milk yield in the western highlands of the country have been studied (14). The objective of the present study was to estimate the effects of genotype and environment on milk production and reproductive traits of dairy cattle in Cameroon's western highlands. Ten types of genetic contrasts were considered for the traits as follows: crosses involving various proportions of Gudali, White Fulani, Red Fulani and *Bos taurus* (Holstein-Friesian and Jersey) inheritance.

■ MATERIALS AND METHODS

Environment

The study was carried out at the dairy cattle research section of the Bambui Regional Centre of the Institute of Agricultural Research for Development (IRAD-BRC), located on the western highlands in the Northwest province. The Bambui Regional Centre is located at latitude 6°30' N, longitude 10°15' E, and about 21 km northwest of Bamenda. Research activities of the Centre cover the West and Northwest provinces, which form the western highlands of Cameroon. The western highlands (WHL) or western high plateau (WHP) cover an area of 31,150 km^2, which is equal to 6.6% of the national territory. It is a hilly complex with altitudes ranging from 700 m for the lowest areas to above 3000 m. The mean altitude is 1500 m with most of the land lying above 2000 m (41).

Weather on the western highlands is described as tropical but of Cameroonian mountain type. Mean annual rainfall varies from 1500 to 2630 mm. Mean relative humidity registered on WHL between 1970 and 1990 was 40% for the dry season and 68% for the rainy season, with an absolute minimum of 22%. The rainfall has a unimodal pattern and runs from March to October. The dry season is fresh from November to December, then hot until March. Soils are largely volcanic.

The Bambui Centre covers an area of 838 ha at an altitude ranging from 1600 to 1982 m. The main farm where dairy cows are kept covers 136 ha. Weather conditions registered from 1970 to 1990 revealed a mean annual temperature of 20.2 ± 1.2°C, a mean relative humidity of 73.3 ± 12.7%, and, from 1974 to 1995, a mean annual temperature ranging from 9.8 to 25°C, with a general mean of 19°C (7), and a mean annual rainfall of 2310.9 ± 196.3 mm. The Centre controlled pastures with natural or improved (exotic) vegetation. Natural vegetation is made of elephant grass (*Pennisetum purpureum*), Kikuyu grass (*Pennisetum clandestinum*), *Hyperrhenia* sp. and *Sporobolus africanus*, which are common. *Leguminosae* include: *Trifolium* sp., *Sida* sp., *Stylosanthes guyanensis, Stylosanthes scabra* and *Desmodium* sp. Among exotic *Gramineae* species introduced are: *Brachiaria ruziziensis, Setaria sphaceolata, Panicum maximum* and Guatemala grass (*Trypsacum laxum*). Major fodder trees are *Leucaena leucocephala* and *Centosema* sp.

The main animal health problems on WHP have been described (9, 12, 30, 31, 38). Permanent health problems in the region are chiefly due to ticks and tick borne diseases, gastrointestinal and pulmonary parasitism, bovine tuberculosis, bovine brucellosis, mastitis, foot and mouth disease, infectious keratoconjunctivitis and leukolymphoid. Preventive measures are taken on-station against these diseases.

Herd description and animal management

The dairy herd resulted firstly from successive live imports of Holstein-Friesian and Jersey breeds and semen. Breeding was done naturally and by artificial insemination. The mating design (Table I) produced the seven cow genotypes in this study: purebred Holstein-Friesian (H), Jersey (J); exotic x local crosses, i.e. Holstein-Red Fulani F_1 (H_1RF_1), Holstein-Gudali (H_1G_1), Jersey-White Fulani (J_1WF_1) and Jersey-White Fulani backcrosses (J_3WF_1, J_7WF_1), Holstein x Holstein (HH), Holstein♂ x Gudali♀ F_1 (H_1G_1), Holstein♂ x Red Fulani♀ F_1 (H_1RF_1), Jersey x Jersey (JJ), Jersey♂ x White Fulani♀ F_1 (J_1WF_1), and Jersey backcrosses (J_3WF_1 and J_7WF_1). Holsteins were not crossed with White Fulani (smaller in size) to avoid complications during calving (Ndumbe, pers. commun.).

Management was consistent throughout the period of the study. Artificial insemination was the major breeding method for dairy cows. The heifers were inseminated at 18 to 24 months of age and weighed 200-370 kg. After calving, calves were left with their dams for 2 to 3 days to allow them to suckle the maternal colostrum, then they were subjected to bottle-feeding with fresh warmed milk. The calves were then separated from their dams and kept in isolated individual calf pens in the cowshed until weaning at 16 weeks (about 4 months or 112 days, and from 65 to 120 kg of body weight). During that period they were bucket-fed whole milk warmed at 38°C twice daily (morning and evening) between 6–7 h, and 16–17 h. The litter, usually made of hay (dried grass) was changed regularly to limit infections. Water was given ad libitum. Regular diets made of concentrate and cut grass were provided. Weaned calves at 16 weeks were sent to pasture were they formed a herd with heifers. A second herd grouped lactating cows, and a third was made of non-lactating cows. The management pattern was semi-intensive. During the rainy season animals were put on natural pastures (*Sporobolus*) or improved ones (*Brachiaria ruziziensis* and *Pennisetum purpureum*). In the dry season, they were mainly fed silage made of Guatemala grass and *Pennisetum*, together with *Sporobolus* hay. They also grazed standing *Brachiaria* hay in paddocks and received supplements of fresh Guatemala grass. Milking was essentially performed with milking machines twice a day, at 6 h and 16 h. During milking and immediately after, cows received a concentrate diet. Routine work consisted in attributing identification numbers to calves, and data recording: calf birth date, birth weight, sex, calving season, dam age at calving, monthly weighing, dehorning, vaccinations (during the first six weeks), prophylaxis against trypanosomosis and helminths (administration of Berenil, Trypamidium, Panacur) and against ectoparasites (ticks). The animals were sprayed twice a week in the rainy season and once a week in the dry season with Supona or Tigal. Dairy recording included milk yields, parity, dry update, date and reason for culling.

Statistical analysis

Of the 540 lactations at the beginning, 364 were included in the analysis: 176 lactations were removed for non-conformity with the editing criteria (inclusion/exclusion) retained. Thus, all lactations following abortions and those of sick cows (mastitis) were removed (24 lactations). Likewise, all lactations from cows of unknown or doubtful paternity, or of unknown birth date were removed (101 lactations). All the data from hybrid cows (exotic x local) of less than three years or those from exotic cows of more than 14 years were removed (51 lactations). The data retained for the analysis were those covering effectively the period from 1974 to 1994 inclusive. For analytical purposes, cow age at calving (AGE) was grouped into six age classes as follows: all cows between 2 and 4 years exclusive were grouped into AGE 1, those between 4 and 5 years exclusive into AGE 2, those between 5 and 6 years exclusive into AGE 3, those between 6 and 7 years exclusive into AGE 4, those between 7 and 8 years exclusive into AGE 5, those from 8 years and above into AGE 6. All the parities above 8 were brought back to 8. Table II presents the distribution of records by genotype.

The traits analyzed were milk yield (MYLD) in kilograms, lactation length (LL) in days, calving interval (CI) in days, dry period (DP) in days, and annualized milk yield (AMP) in kilograms. The latter was calculated as follows: AMP = (MYLD/CI) x 365. To estimate CI, it is admitted that the cow mean

Table I

Mating plan for dairy improvement on Cameroon's western high plateau

Sire genotype	Dam genotype						
	Holstein (H)	Jersey (J)	Gudali (G)	Red Fulani (RF)	White Fulani (WF)	J_1WF_1	J_3WF_1
Holstein	HH		H_1G_1	H_1RF_1			
Jersey		JJ			J_1WF_1	J_3WF_1	J_7WF_1

H = Holstein; J = Jersey; G = Gudali; RF = Red Fulani; WF = White Fulani; J_1WF_1 = Jersey x White Fulani F_1; J_3WF_1 = Jersey backcross; H_1G_1 = Holstein x Gudali F_1; H_1RF_1 = Holstein x Red Fulani F_1; J_7WF_1 = double backcross

Table II

Distribution of records by genotype

Cow genotype	Num. of records	Num. of cows	Num. of sires	Num. of lactations	Lactations per cow	Maximum parity
J	70	32	11	108	3.4	8
J_1WF_1	64	10	9	68	6.8	14
J_3WF_1	56	19	11	54	2.8	8
J_7WF_1	10	5	5	10	2.0	6
H	84	33	11	141	4.3	8
H_1RF_1	16	5	2	18	3.6	9
H_1G_1	64	13	5	66	5.1	9
Total	364	114	54	465	4.1	–

J = Jersey; J_1WF_1 = Jersey x White Fulani F_1; J_3WF_1 = Jersey backcross; J_7WF_1 = double backcross; H = Holstein; H_1RF_1 = Holstein x Red Fulani F_1; H_1G_1 = Holstein x Gudali F_1

gestation length is 284 days and the mean period between calving and the following pregnancy is 60 days postpartum. Since each cow had at least two pregnancy opportunities before being culled for infertility, the upper limit of the calving interval was estimated at 730 (2 x 365) days. Therefore, all estimates of CI less than 300 days or above 730 days were removed. DP is defined as the period between the end of lactation (dry off) and the following calving (starting of the next lactation). The minimum value of DP has been estimated at 30 days and the upper value at 730 days. Table III presents the distribution of data analyzed by trait and genotype.

Data were analyzed by fitting the following fixed effects linear model using the general linear models procedure of the Statistical Analysis Systems, version 6.12 (35).

$$P_{ijklm} = \mu + B_i + S_j + C_k + P_l + \varepsilon_{ijklm}$$

where P_{ijklm} represents the performance record (milk yield, lactation length, annualized milk yield, calving interval, dry period); μ is the overall mean; B_i is the effect due to the cow genotype i (i = H, J, H_1G_1, H_1RF_1, J_1WF_1, J_3WF_1, J_7WF_1); S_j is the effect due to the calving season (j = dry season, rainy season) or S_j is the effect due to the month of calving (j = January to December), or S_j is the effect due to the year of calving (j = 1974 to 1994); C_k is the effect due to the age class of the cow at calving (k = 1 to 6); P_l is the effect due to the parity (rank or lactation number) of the cow (l = 1 to 8); ε_{ijklm} is the residual effect which is assumed to be independent and randomly distributed with a mean of zero and variance σ^2.

Preliminary analysis to verify the pertinence of the model showed no significance of possible interactions (P > 0.05) between the effects in the model. Therefore, all two-way interactions were dropped.

In the same way, due to the absence of normality of dry period data distribution and the non-homogeneity of the variance, data were transformed using log transformation [LGDP = log (DP)]. On the other hand, age at first calving was analyzed by fitting the data to a fixed-effect linear model, which consisted of the cow genotype and season of calving:

$$A_{ijk} = \mu + B_i + S_j + \varepsilon_{ijk}$$

where A_{ijk} is the cow age k (k = 1 to 6) of genotype i, born in season j; μ is the overall mean; B_i is the genotype (i = H, J, H_1G_1, H_1RF_1, J_1WF_1, J_3WF_1, J_7WF_1); S_j is the calving season, year or month (j = dry season, rainy season; January to December; 1974 to1994); ε_{ijk} is the residual effect associated with the cow k assumed to be identically and independently distributed with a mean of zero and variance σ^2. Lastly, the breeding plan in this study allowed the analysis of contrasts by comparing different genotypes with variable exotic and local blood for their performances in all the production and reproduction traits. Comparisons of genotypes were as follows: J_1WF_1 vs J_3WF_1, J_1WF_1 vs J_7WF_1, J_3WF_1 vs J_7WF_1, J_1WF_1 vs H_1RF_1, J_1WF_1 vs H_1G_1, J_3WF_1 vs H_1RF_1, J_3WF_1 vs H_1G_1, J_7WF_1 vs H_1RF_1, J_7WF_1 vs H_1G_1, H_1RF_1 vs H_1G_1.

■ RESULTS

Cow production traits

Factors, which affect cow production traits, are presented in Table IV. The genotype significantly influenced MYLD (P < 0.001), AMP (P < 0.001) and LL (P < 0.01). The calving year (CY) significantly influenced MYLD (P < 0.001) and AMP (P < 0.01). Parity and age at calving did not affect MYLD and AMP, but affected LL (P < 0.05). As expected, it was observed for most of the genotypes an increase of MYLD and AMP until parity five. Table V presents least squares means and standard errors for cow production and reproduction traits. Four genotypes (J, J_7WF_1, H et H_1G_1) among the seven studied had MYLD and AMP above the overall mean. On the other hand, H_1RF_1, J_1WF_1, and J_3WF_1 had MYLD largely below the overall mean, contrary to the latter AMP, which was well above the overall mean. The LL value equals the overall mean for J; its value is largely above the overall mean for H and H_1G_1, close to the overall mean for J_3WF_1 and J_7WF_1, low for J_1WF_1 and H_1RF_1. Among the hybrids resulting from crossbreeding J and WF, J_7WF_1 were better than J_3WF_1 and J_1WF_1 for MYLD, with +256 kg, s.e. 4.3, and +424 kg, s.e. 65.46, respectively, and for AMP, with +384 kg, s.e. 28.3, and +387 kg, s.e. 16.9, respectively. However, these differences were not significant in both cases (P > 0.05). H_1G_1 were better than H_1RF_1 for MYLD, with +353 kg, s.e. 60.3, and AMP, with +22 kg, s.e. 3.6, but these differences were not significant (P > 0.05).

Table III

Distribution of data by trait and genotype

Traits	J	J_1WF_1	J_3WF_1	J_7WF_1	H	H_1RF_1	H_1G_1	Total
Cow production								
MYLD	49	64	50	10	62	56	61	305
AMP	26	42	29	5	35	43	50	191
LL	49	64	50	10	62	56	61	305
Cow reproduction								
CI	49	64	50	10	62	56	50	305
DP	49	64	50	10	62	56	61	305
AFC	34	16	19	6	34	7	61	127

J = Jersey; J_1WF_1 = Jersey x White Fulani F_1; J_3WF_1 = Jersey backcross; J_7WF_1 = double backcross;
H = Holstein; H_1RF_1 = Holstein x Red Fulani F_1; H_1G_1 = Holstein x Gudali F_1

MYLD = milk yield; AMP = annualized milk yield; LL = lactation length; CI = calving interval; DP = dry period; AFC = age at first calving

Elsewhere, if J and H confirmed their reputation as good milkers, J_7WF_1 were better than J for MYLD and AMP, while H_1G_1 were better than J for MYLD, with +83 kg, s.e. 17.2, and almost as good as J for AMP, with –18 kg, s.e. 3.1. J and H performances were well below those obtained in their country of origin (USA) indicating the presence of a genotype x environment interaction. This suggests a better adaptation of the crosses compared to purebred exotics, as has been reported (10, 25, 40). Cow reproductive traits were affected by CY (P < 0.05–P < 0.001), while the genotype affected (P < 0.01) AFC only.

Least squares means for CY depicted substantial interannual variations in MYLD and AMP (Figure 1) and in LL and CI (Figure 2). MYLD and AMP peaked in 1976 (7515 kg and 5981 kg, respectively) and again in 1978 (3025 kg and 2682 kg, respectively), and then decreased progressively (overall average of 1500 kg in MYLD) until 1992. The lowest levels in MYLD and AMP (521 kg and 703 kg, respectively) were obtained in 1989. From 1993 on, an increase was observed in the production. The lactation length presented a decrease from 228 days to 175 days in 1977, followed by an important increase in 1978, and then by

Table IV

Least squares analysis of variance

Traits	Num. of records	B	CS	CY	P	AGE	CV	R^2	RE
Cow production									
MYLD (kg)	305	***	–	***	*	**	45.7055	0.4734	759.074
LL (days)	305	**	–	–	–	–	36.3319	0.1986	86.6534
AMP (kg)	197	***	–	**	–	–	49.5128	0.4517	734.1426
Cow reproduction									
DP (days)	305	–	–	**	–	–	56.0612	0.1568	280.522
CI (days)	305	–	–	*	–	–	94.9631	0.1908	294.250
AFC (days)	127	**	–	***	–	–	34.0677	0.6134	417.999

B = cow genotype; CS = calving season; CY = calving year; P = parity; AGE = age class; CV = coefficient of variation; R^2 = coefficient of determination; RE = residual error; MYLD = milk yield; LL = lactation length; AMP = annualized milk yield; DP = dry period; CI = calving interval; AFC = age at first calving

*** Very highly significant (P < 0.001); ** Highly significant (P < 0.01); * Significant (P < 0.05); – Non significant (P > 0.05)

Table V

Least squares means (standard errors) for cow production and reproduction traits

Traits	General mean	J	J_1WF_1	J_3WF_1	J_7WF_1	H	H_1RF_1	H_1G_1
Production								
MYLD (kg)	1703	1744	1320	1488	1744	2321	1474	1827
	(12.1)	(180.8)	(170.9)	(208.3)	(315.8)	(180.6)	(243.2)	(179.5)
AMP (kg)	1557	1652	1194	1197	1581	2027	1612	1634
	(17.7)	(209.6)	(174.6)	(240.2)	(434.7)	(202.0)	(261.5)	(193.4)
LL (days)	237	236	210	224	247	280	204	260
	(1.4)	(20.6)	(19.5)	(23.8)	(36.0)	(20.6)	(27.8)	(20.5)
Reproduction								
CI (days)	286	210	317	296	344	250	301	287
	(4.7)	(70.2)	(66.4)	(80.9)	(122.7)	(30.1)	(94.4)	(69.7)
DP (days)	148	125	193	176	217	124	138	106
	(4.5)	(66.8)	(63.2)	(76.9)	(116.7)	(66.7)	(89.9)	(66.3)
AFC (days)	1315	1025	1582	1538	1452	1288	877	1440
	(121.5)	(84.1)	(119.4)	(121.2)	(203.9)	(90.9)	(462.8)	(182.6)

J = Jersey; J_1WF_1 = Jersey x White Fulani F_1; J_3WF_1 = 3/4Jersey, 1/4WF; J_7WF_1 = 7/8Jersey, 1/8 WF;
H = Holstein; H_1RF_1 = Holstein x Red Fulani F_1; H_1G_1 = Holstein x Gudali F_1

MYLD = milk yield; AMP = annualized milk yield; LL = lactation length; CI = calving interval; DP = dry period; AFC = age at first calving

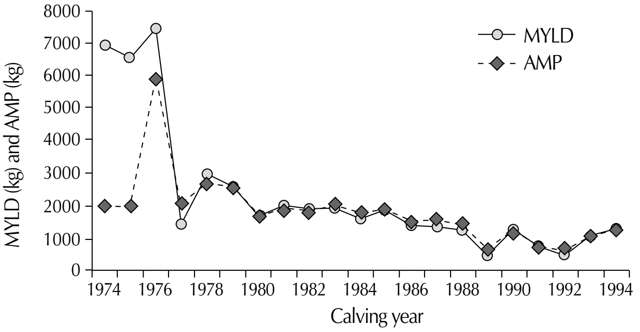

***Figure 1:** Yearly variation of least squares means for lactation and annualized milk yields. MYLD = milk yield; AMP = annualized milk yield.*

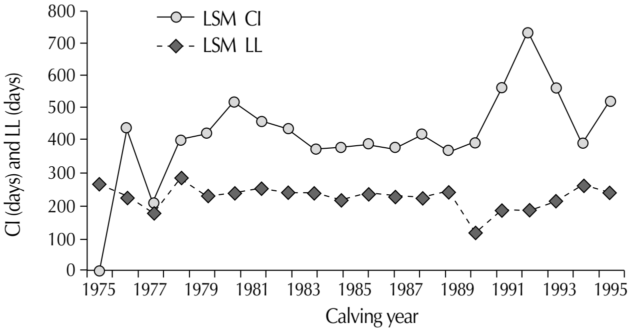

***Figure 2:** Yearly variation of the calving interval (CI) and lactation length (LL).*

a series of fluctuations until 1988. The lowest value was obtained in 1989, followed by a constant rise until 1994.

Table V presents least squares means and standard errors for production and reproduction traits for all the cow genotypes studied. All the crosses except H_1G_1 and J_7WF_1 showed negative constants for LL (LL values less than the overall mean). The difference was –27 days, s.e. 0.2, for J_1WF_1, –33 days, s.e. 2.4, for H_1RF_1, and –13 days, s.e. 0.2, for J_3WF_1. Pure breeds presented LL equal to the overall mean value for J, and longer for H (+43 days s.e. 3.4). It was observed that LL was slightly longer for H_1G_1 than for J, but the difference was not significant.

In general, results from comparison between specific genotypes showed that H_1G_1 crosses produced more milk than H_1RF_1 (+353 kg, s.e. 53.4, P > 0.05), J_1WF_1 (+507 kg, s.e. 22.8, P < 0.01), J_3WF_1 (+339 kg, s.e. 27.7, P < 0.05), and J_7WF_1 (+83 kg, s.e. 4.2, P < 0.05).

Cow reproduction traits

Results of least squares analysis of variance for cow reproductive traits are presented in Table IV, and contrasts between cow genotypes are presented in Table VI. The genotype did not represent a significant source of variation for DP (P > 0.05) and CI (P > 0.05), but it affected AFC (P < 0.01). The calving season (CS) did not significantly (P > 0.05) affect any trait. However, CY significantly affected DP (P < 0.01), CI (P < 0.05) and AFC (P < 0.001). Parity (P) and AGE did not influence reproductive traits (P > 0.05), but affected MYLD (P < 0.05 and P < 0.01, respectively).

Interannual fluctuations of CI and LL are presented in Figure 2. From 1976 to 1980, there was averagely an increase in CI, then followed a decrease up to 1989, and then an increase up to 1991. CI values were high from ages four to seven. The lowest CI was observed at age three (205.9 days, s.e. 182.8, for Jerseys).

Table VI

Results of the contrasts between genotypes

N°	Contrasts	Traits					
		MYLD	LL	AMP	DP	CI	AFC
1	J_1WF_1 vs J_3WF_1	–	**	–	–	–	–
2	J_1WF_1 vs J_7WF_1	–	–	–	–	–	–
3	J_3WF_1 vs J_7WF_1	–	–	–	–	–	–
4	J_1WF_1 vs H_1RF_1	**	–	**	–	–	–
5	J_1WF_1 vs H_1G_1	**	**	**	. σ	–	–
6	J_3WF_1 vs H_1RF_1	. σ	–	**	–	–	–
7	J_3WF_1 vs H_1G_1	**	–	***.	–	–	–
8	J_7WF_1 vs H_1RF_1	–	–	–	–	–	–
9	J_7WF_1 vs H_1G_1	–	–	–	–	–	–
10	H_1RF_1 vs H_1G_1	–	*	–	–	–	–

J_1WF_1 = Jersey x White Fulani F_1; J_3WF_1 = 3/4Jersey, 1/4WF; J_7WF_1 = 7/8Jersey, 1/8 WF; H_1RF_1 = Holstein x Red Fulani F_1; H_1G_1 = Holstein x Gudali F_1

MYLD = milk yield; LL = lactation length; AMP = annualized milk yield; DP = dry period; CI = calving interval; AFC = age at first calving

*** Very highly significant (P < 0.001); ** Highly significant (P < 0.01); * Significant (P < 0.05);. σ Value of P close to significance (P~0.05); – Non significant.

DP variation was not consistent with the age of the cow at calving. Results showed that AFC of cows born in the rainy season was 105 days, s.e. 25.6, shorter than those of cows born in the dry season (962 days, s.e. 311.6, vs 1067 days, s.e. 372.3, respectively; $P < 0.05$).

Least squares means for cow production traits (Table V) showed that J_1WF_1, J_3WF_1, J_7WF_1 and H_1RF_1 crosses calved later than H_1G_1 crosses (+30 days, s.e. 7.2, $P < 0.05$; +9 days, s.e. 1.3, $P > 0.05$; 57 days, s.e. 22.8, $P > 0.05$; +14 days, s.e. 9.7, $P > 0.05$; respectively).

Jersey and Holstein purebreds had shorter AFC than their respective crosses (except for H_1RF_1). Elsewhere, Jersey crosses showed a decrease in AFC concomitant with an increase in exotic blood level. However, differences between CI values for different genotypes were not significant ($P > 0.05$).

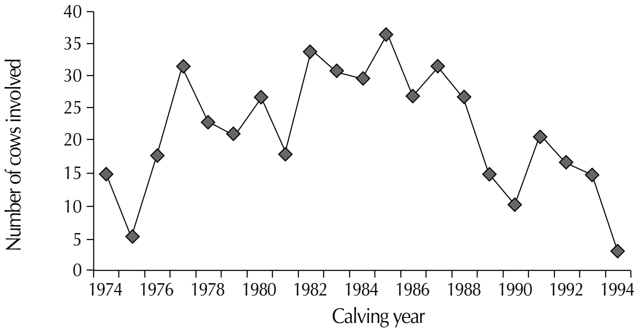

Figure 3: *Yearly variation of dairy cows totals.*

■ DISCUSSION

Fixed effects

Many authors in previous studies on dairy cattle (14, 15, 18, 20, 34, 40, 44) reported significant effects of CY on MYLD, LL, AMP and CI. These observations are confirmed in this study. Interannual variations in milk production have been attributed to fluctuations in feed (pastures) availability and quality through the seasons (6). On the other hand, the variations have been attributed to the variation in the genetic structure of the herd from one year to another (40). This might have been the case in the present study as purebreds were gradually replaced by crosses. In addition, these changes may be associated with changes in temperature and relative humidity. Over the twenty-year period, temperatures increased while rainfall dropped due to the phenomenon of climate change (2). These two environmental factors have been shown to have a negative effect on milk production, particularly in genotypes with minimal zebu breeding in the tropics (3), and to indirectly affect pasture quality (32) and digestibility (6).

The fluctuations in milk production could also be associated with changes in the quality and availability of concentrate supplements and maize silages offered to lactating cows over the years (40). Differential responses to heat stress in exotic genotypes, and their variable susceptibility to various diseases under similar conditions have been reported (21, 22, 23). Heat stress and diseases, coupled with untimely and infrequent interventions in some years, may have contributed to the observed trends in milk performance (40). A component of the observed trends may have originated from variations in the genetic quality of imported semen over the years (24). However, the initial factors determining the genetic quality of imported semen were the cost the Institute had to bear, the availability of funds, and the origin of semen (mainly France and the USA). In addition, from 1974 to 1988, the number of Jerseys and Holsteins usually peaked with fresh imports, but decreased progressively thereafter, resulting from high mortalities due to adaptability problems. By 1989, exotic purebreds were all replaced by their crosses (Figure 3).

The month of calving did not have a significant effect on AMP, and no significant effect of the season of calving was observed on MYLD. This indicates that the dry and rainy season feed supplementation policies on the station were efficient, thus no particular month was recommended for calving. On the contrary, the year of calving significantly influenced ($P < 0.001$) all the traits except AFC. This result is concordant with that of Thorpe et al. (44) for AFC with crosses in Kenya, but it is contrary to those of Tawah et al. (40) in Wakwa. In the present study, and contrary to the findings of other authors (34, 40, 44) for CI and AMP, P did not influence any of the production and reproduction traits, except MYLD. This could suggest that environmental conditions such as the climate on the Cameroon western highlands favored a better expression of certain potentials compared to other zones of studies (e.g. Wakwa).

Genetic effects

As previously observed (36), most published studies on crossbreeding between taurin (*Bos taurus*) and zebu (*Bos indicus*) in the tropics have so far been limited to some isolated exotic breeds. This study, like that of Tawah et al. (40) in Wakwa and Kamga et al. (14) in Bambui, involved a minimum of two exotic breeds (Holstein-Friesian and Jersey) and three local breeds (White Fulani, Red Fulani and Gudali), all of them studied simultaneously under the same environmental conditions. Furthermore, in this study Holstein-Friesian was crossed with two local breeds (Gudali and Red Fulani), as opposed to the study in Wakwa. Among crossbreds, H_1G_1 performed better than H_1RF_1 and J_1WF_1 for MYLD, AMP, CI and DP (Table III). This occurred with a mean parity per cow of 5.1 for Holstein, largely above the overall mean of 3.96 (Table V). This finding is of great importance to local dairy production. It was observed that F_1 crosses performed better for MYLD, AMP and AFC in this study than in that of Tawah et al. (40), and it confirmed the report of Negussie et al. (33) and the conclusion of McDowell (25) on different studies in the tropics. On the contrary, the CI of 287 days was shorter than that of 384 days reported by Tawah et al. (40), and much better than the 437 days reported by McDowell (25).

The degree of superiority of the crosses is related to their environment. Meanwhile, the phenotype is the expression of the genotype as influenced by the environment (14, 25). All of this may explain the superiority of the overall performance of crossbreeds in this study compared to that of crossbreeds from other zebus of low dairy potentials such as Arsi and Sinhala reported elsewhere (5, 16, 36, 37, 39, 40). The performance of crosses in Bambui, which included White Fulani crosses, though it is considered as a low dairy potential zebu breed, is rather comparable with the performance of crosses obtained from crossbreeding *Bos taurus* dairy breeds with high dairy potential zebu breeds such as Gir, Guzerat, Sahiwal and Tharparkar (1, 4, 19, 44). While environmental variations may explain some of the differences between the present study and the reports mentioned above, additive breed differences (dairy) between the *Bos indicus* cattle used may also play a role (18, 34). This explains the hypothesis that the difference in performance between crosses depends on the previous selection history of the dam genotype.

Thus, the superiority of WF crosses observed in this study, with an overall MYLD mean greater than those reported in the literature, suggests differences in the genetic structure of the various populations concerned.

Results on F_1 crosses in this study, as already reported in most crossbreeding studies, confirmed their consistently better ranking in all the traits (5, 14, 25, 33, 37, 39, 40). This is due to the positive heterotic effect or hybrid vigor, which results from a high heterozygosis (100%). H_1G_1 in this study were 1.2 time (1827 kg vs 1554 kg) better than elsewhere (40) for MYLD and 1.05 time (1634 kg vs 1555 kg) better for AMP. Similarly, Holstein-Friesian performed better in Bambui than in Wakwa, with the overall MYLD mean in Bambui 1.6 time (3360 kg vs 2626 kg) better than the one in Wakwa. This result suggests a genotype-environment interaction. Another explanation could be that the quality of imported semen used in artificial insemination in Bambui was of a higher genetic grade than the one used in Wakwa, since they were not acquired from the same sources (USA for Bambui, France for Wakwa). The performance of the various genotypes in this study, despite the fluctuations observed presented interesting results consistent with results obtained elsewhere (5, 34, 37). The Holstein crosses (H_1G_1, H_1RF_1) were better than J_1WF_1 in this study in contrast to other reports (33) where Jersey crosses (Jersey x Boran F_1) were best. The main explanation for the apparent reversal in ranks lies in the fact that the dam breeds were different. The progressive improvement of Jersey crosses performance with increasing exotic blood level (J_1WF_1, J_3WF_1 and J_7WF_1) for MYLD, AMP, LL and CI is comparable to results obtained elsewhere (40), but contrasts with Ethiopian results (33). The results show that the dairy performance of J_7WF_1 crosses was comparable to those of J when considered in the same environmental conditions. The mean lactation number per cow for J_3WF_1 and J_7WF_1 was less than the overall mean (2-3 vs 4; Table II). This suggests a dairy production life span relatively shorter for cows with high exotic blood levels under the conditions of this study although the number of records on J_7WF_1 was not sufficient to draw definitive conclusions.

Previous studies on reproduction traits in Holstein, Jersey and their crosses with local breeds at Bambui showed mortality rates of 12.7% for Holstein, 8.9% for Jersey, 6.6% for Holstein crosses and 5.8% for Jersey crosses (13). Calving rates for these genotypes were 75.4, 79.5, 83.2 and 78.8%, respectively (13). These reproduction traits cited above coupled with other studies (14) show good adaptability of crosses on the WHL. The overall improvement of milk production of crossbred dairy cattle in Bambui was as follows: 2.6 times for J_1WF_1 vs WF, 2.9 times for J_3WF_1 vs WF, 3.4 times for J_7WF_1 vs WF, 4.3 times for H_1RF_1 vs RF, and 3.7 times for H_1G_1 vs G (24). These results indicate the inadequacy of the local White Fulani, Red Fulani and Gudali as dairy animals.

■ CONCLUSION

Results on F_1 crosses developed in the Cameroon's western high plateau showed that H_1G_1, H_1RF_1, J_3WF_1 and J_7WF_1 were superior to J_1WF_1 for milk production. Jersey backcrosses (J_3WF_1 and J_7WF_1) showed good milking potentials, but their relative short milking life span (< 3 years) appeared to be a handicap. The improvement of milk production of Jersey crosses due to increasing exotic blood levels was obvious. H_1G_1 crosses were the best for almost all production and reproduction traits, thus positioning Gudali as the best or better local dam breed among those studied.

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Résumé

Djoko T.D., Mbah D.A., Mbanya J.N., Kamga P., Awah N.R., Bopelet M. Croisement des bovins pour la production laitière sous les tropiques : effets des facteurs génétiques et environnementaux sur les performances des génotypes améliorés des hauts-plateaux de l'Ouest Cameroun

Trois cent soixante-quatre données sur la production laitière, obtenues à partir de 540 lactations assurées par 145 vaches, élevées au Centre régional de recherche agricole pour le développement de Bambui, dans les hauts-plateaux de l'Ouest Cameroun, et ayant vêlé entre 1974 et 1994, ont été analysées afin de rechercher les effets du génotype et de l'environnement sur les traits de production et de reproduction. Les génotypes bovins concernés ont été les suivants : Holstein-Frison (H), Jersiais (J), Holstein-Red Fulani F_1 (H_1RF_1), Holstein-Goudali F_1 (H_1G_1), Jersiais-White Fulani F_1 (J_1WF_1) et les croisements de retour Jersiais-White Fulani (J_3WF_1, J_7WF_1). Les effets du génotype, de la saison, de l'année de vêlage, de la parité et de l'âge à la première mise bas (APM) ont été analysés. Le rendement laitier (RL), la durée de lactation (DL), la production laitière annualisée (PLA), l'intervalle entre vêlages (IV) et la période sèche (PS) ont aussi été étudiés. Les génotypes F_1 (H_1G_1, J_1WF_1, H_1RF_1) et les croisements de retour (J_3WF_1, J7WH1) ont été comparés. Les génotypes H_1G_1 ont été supérieurs aux génotypes H_1RF_1 et J_1WF_1 pour les traits RL, PLA, DL, IV et PS. De même pour APM, les H_1G_1 ont été supérieurs aux J_1WF_1, J_3WF_1 et J_7WF_1, mais ils ont été inférieurs aux H_1RF_1. Les croisements de retour Jersiais ont été supérieurs aux Jersiais F_1. Les génotypes F_1 ont amélioré le rendement laitier des races locales de 2,6 (J_1WF_1 vs WF) à 4,3 fois (H_1RF_1 vs RF). Parmi les génotypes F_1, les H_1G_1 ont été les meilleurs.

Mots-clés : Bovin – Croisement – Production laitière – Facteur de rendement – Tropiques – Cameroun.

Resumen

Djoko T.D., Mbah D.A., Mbanya J.N., Kamga P., Awah N.R., Bopelet M. Cruces de ganado para la producción láctea en los trópicos: efectos de los factores genéticos y ambientales en el rendimiento de los genotipos mejorados en las mesetas altas de Camerún del Oeste

Trescientos sesenta y cuatro registros de producción láctea obtenidos a partir de 540 lactaciones de145 vacas, las cuales parieron entre 1974 y 1994 en el Centro de Investigación Agrícola para el Desarrollo de Bambui, en las tierras altas del oeste de Camerún, se analizaron para los efectos del genotipo y el medio ambiente sobre los rasgos de producción de leche y la reproducción. Los genotipos de las vacas fueron Holstein-Friesian (H), Jersey (J), Holstein-rojo Fulani F_1 (H_1RF_1), Holstein-Gudali F_1 (H_1G_1), Jersey-blanco Fulani F_1 (J_1WF_1) y Jersey-blanco Fulani cruces repetidos (J_3WF_1, J_7WF_1). Se analizaron los efectos del genotipo, estación y año de parto, número de parto y edad al primer parto (AFC). También fue analizado el rendimiento de lactación de leche (MYLD), la duración de la lactación (LL), la producción de leche anual (AMP), el intervalo entre partos (CI) y el periodo seco (DP). Se compararon los cruces F_1 (H_1G_1, J_1WF_1, H_1RF_1) y los cruces repetidos (J_3WF_1, J_7WF_1). H_1G_1 fueron superiores a H_1RF_1, J_1WF_1 y J_3WF_1, con respecto a MYLD, AMP, LL, CI, y DP. Para AFC, H_1G_1 fue superior a J_1WF_1, J_3WF_1, J_7WF_1 pero inferior a H_1RF_1. Los cruces repetidos de Jersey fueron superiores a Jersey F_1. La producción de leche de los cruces F_1 varió de 2,6 veces (J_1WF_1 vs. WF) a 4,3 veces (H_1RF_1 vs. RF) del rendimiento de las razas locales. Entre los cruces F_1, H_1G_1 fue el mejor.

Palabras clave: Ganado bovino – Cruzamiente – Producción lechera – Factor de rendimiento – Trópicos – Camerún.