Rev. Brasil. Genet. 18, 2, 221-228 (1995)
(Brazil. J. Genetics)

Effects on milk yield of crossbreeding Zebu and European breeds in the Sudan*

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ABSTRACT

Data from Sudan were analyzed, representing a herd established in 1907 with Butana, a Zebu breed, and crossbred offspring by Ayrshire, Holstein, Guernsey and Milking Shorthorn sires. Mean milk yield was 2508 kg; mean calving interval was 461 days. Statistical analysis of 4121 lactation records of 892 cows was by method of ordinary least squares analysis of variance. Mathematical model included year, month and age at parturition, percentage of European breed composition and interactions of breed composition. Calving interval was included as an independent variable in some models (dependent variable was milk yield). All animals were at least 29% Butana. Data covered 27 years; additional analyses were performed on two data subsets representing the best 14 and poorest 13 years. Estimates of heterosis for milk yield were .9 and 6.0% for Ayrshire and Holstein F_1 crossbreds if data were not adjusted for calving interval, or 15.1 and 16.5% if adjusted. Overall, yields were highest for Holstein crossbreds, lowest for Ayrshire crossbreds, with three breed (Ayrshire, Holstein, Butana) crossbreds intermediate. Estimates of yield of 91 crossbred groups were obtained by response surface methodology with a breed composition of Holstein, Ayrshire and Butana. Overall and in good years, results suggested yields increased with up to 12/16 European breeding of either Holstein or Ayrshire, although maximum yield when adjusted for calving interval resulted from animals 6/16 Holstein, 6/16 Ayrshire, and 4/16 Butana. In poor years, results were similar; not adjusted for calving interval, highest yields were from 8/16 Holstein, 4/16 Ayrshire and 4/16 Butana crossbreds. Results thus suggest that under the environmental conditions encountered, upgrading of Butana to at least 12/16 Holstein or Ayrshire would be associated with maximum yields on the average in good years, and would be associated with only a small decline in yields in poor years.

INTRODUCTION

Butana is one of four major Zebu daiy breeds in the world. These are the Sahiwal and Red Sindhi from Pakistan and the Butana and Kenana from Sudan. Dual purpose Zebu breeds include Tharparkar, Gir (Gyr), Kankrej (Guzerat) and Hariana from India. These eight Zebu breeds plus Criollo cattle from Latin American are the main tropical breeds considered for crossbreeding for dairy production, though draft breeds such as Ongole (Nellore) and beef breeds such as Brahman have been tried. Butana milk production is estimated at about 2000 kg per lactation under practical conditions, comparable to that of Red Sindhi and Tharparkar, and slightly less than for Sahiwal and slightly higher than for other tropical breeds (Osman, 1983). Chaudhry *et al.* (1993) found that performance of Holstein x Sahiwal crossbreds was superior to that of Jersey x Sahiwal

* Florida Agricultural Experiment Station Journal Series No. R-03848.

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crossbreds in Pakistan, except for age at puberty. Crossing with a beef breed such as Brahman can be used as a system for dual purpose cattle, even with modest supplementation with concentrates (Fernandez-Baca *et al.*, 1986).

Heterosis is the advantage of crossbreds for a given trait over the average performance of the parental breeds. For reproduction, overall survivability, and profitability, crossbreds may be superior to either parent breed, but for traits such as milk yield, when one breed is much better than the other, crossbreds may not reach the level of the better breed even with considerable heterosis. Several studies of crossing Zebu cattle with breeds evolved in temperate climates have suggested average heterosis of 15% for milk yield, -8% for age at first calving and -7.5% for calving interval (McDowell, 1985b). The second crossbred generation (from inter-se mating) is expected to perform at a level below the first because of loss of half of the effects of heterosis. The actual decrease observed could be due to this, differences in environmental conditions, or changes in selection pressure on sires (McDowell, 1985b). Decline from the first to second generation is sometimes twice or more than that expected from loss of heterosis, suggesting that environmental conditions had deteriorated. For example, after formation of the Pitangueiras breed, developed such that the basis was 5/8 Red Poll, and 3/8 Zebu, genetic trends over 15 years were small but positive for mik and milk fat yields, while phenotypic and environmental trends were negative and much higher (Lobo *et al.*, 1982).

Dairy cattle in any geographic area are subjected to natural selection pressure to survive under prevailing environmental conditions. If conditions are not improved, production may not increase. Breeding to increase genetic potential for production without also improving the environment when environmental conditions are not good can be counter-productive. If feed and management requirements of a potentially high producing dairy cow cannot be met, these animals may suffer stress which will result in performance levels lower than native cattle. If stress is severe, it can result in reproductive failure and possibly death under conditions which permit native cattle to remain healthy, reproduce and produce some milk (McDowell, 1985a).

Choice of type of cattle to use is determined largely by the level of feed and management which can be provided, along with other environmental considerations such as veterinary care and presence of endemic diseases. McDowell (1985a) proposed making the choice of breed or breed composition on the basis of level of milk production which the feed available would support. He recommended that for up to 1500 kg of milk per lactation, not more than 25% exotic breeding should be introduced. For 4000 kg or more milk to be produced per lactation, either high grade or purebred animals should be used. In the range of 2000 to 3000 kg, crossbreds should be used, with the ideal combination varying with local conditions and the breeds used. Corley and Hodgson (1970) proposed that if *Bos taurus* cows could produce 1150 kg or more milk per year in a specific environment, they should be used. With adequate nutrition and care, purebred temperate breeds can produce well in the tropics and subtropics.

Objectives of the present study were to characterize milk yield of Butana cows in Sudan, and compare it with yields of crossbreds with European breeds to various degrees.

MATERIAL AND METHODS

Description of data

The Ghurashi dairy farm, located on the East bank of the Nile river at Karthoum North, Sudan, has been a major commercial dairy farm which has provided milk for the cities of Khartoum, Khartoum North and Omdurman since 1907 (Bennett *et al.*, 1948). Detailed milk production and reproductive data were collected for many years (Osman and Russell, 1974). In the early years, the herd consisted of Butana and crossbred cows, obtained by mating Butana cows with Shorthorn and Friesian bulls. Later, crossbred and pure Friesian, Ayrshire and Guernsey bulls were used on crossbred and pure Butana cows. The period for which records were analyzed for the present study was 1952 through 1978. After screening, 4121 records from 892 cows were used. Cows were fed Hejaz berseem (alfalfa) and dura (giant millet) throughout, but in some years (e.g. years of drought) less dura was available since it was used by humans. Since no purebred females were imported, all cows were part Butana, ranging from 29 to 100%. Shorthorn influence decreased in later years and during the entire study was limited to from 0 to 21%. Ayrshire and Guernsey sires were introduced in later years, with the first records for their crossbred daughters appearing in 1967. Holstein-Friesians (as British Friesians) used throughout were represented at levels from 0 to 71%. Additional description of the herd is in El Amin *et al.* (1986).

Statistical analysis

Data were analyzed by the method of ordinary least squares analysis of variance. The mathematical model included year, month and age of parturition, percentages of European breed composition, and interactions between European breed compositions. The response (dependent) variable was milk yield. Calving interval was added to the model in some analyses so that comparisons of breed effects either adjusted or not adjusted for calving interval could be made. Age at parturition was considered a continuous independent variable to the third (cubic) order of polynomial regression. All effects except residual were considered to be fixed. Percentages of breed composition also were considered continuous; inclusion of their interactisons permitted construction of response surfaces (Cochran and Cox, 1957), representing three breeds, Butana, Holstein and Ayrshire. Response surfaces were not constructed involving Shorthorns (low levels of Shorthorn breeding in the data set) or Guernseys and Jerseys (small number of observations).

RESULTS

The first generation of F_1 Friesian-Butana crosses had an average milk yield of 2506 kg, calving interval of 430 days and age at first parturition of 1020 days. Second generation (F_2) values were 2272 kg and 463 and 1034 days. Estimates for Ayrshire-Butana crosses were 2320 kg, and 435 and 10128 days in the first generation, and 1824 kg, and 458 and 1292 days in the second generation.

Response surfaces representing performance according to Butana, Ayrshire and Holstein proportions are in Tables I and II for all data. All estimates have been adjusted for year, month and age at parturition. Although the highest percentage of European breeding attained was 71%, the estimates have been extrapolated to 75% (12/16). Table I provides estimates of least squares mean milk yields for 91 possible combinations of the three breeds, not adjusted for calving interval. For the 27 year period overall, it is apparent that increased milk yield per lactation is associated with increased genetic contributions of Ayrshires and Holsteins. Means increased to 12/16 with both breeds. Lowest yield was associated with pure Butana; highest was for 12/16 Holsteins. Increase with increased European contribution appeared to be curvilinear. Increase from 0/16 to 1/16 Ayrshire was associated with an increased milk yield of 303 kg, with an increase from 11/16 to 12/16 of 144 kg. Comparable changes for Holsteins were 349 and 115 kg. Estimates for the two breed crosses are shown in Figures 1 and 2 also.

Effects of adjustment of yields for calving interval are comparable to expressing yields in terms of yield per day of calving interval. The argument for doing so is that profitability per animal in tropical and subtropical areas may be more closely related to production per day of life than is lactation yield. These estimates are in Table II.

The range in milk yields from 0/16 to 12/16 was 1849 kg for Holsteins and 1699 kg for Ayrshires (Table II) when not adjusted, but only 1075 and 1125 kg when

Table I - Response surface representing least squares means for milk yields of crossbred animals not adjusted for calving interval (all data).

Ayrshire proportion (in sixteenths)	Holstein proportion (in sixteenths)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1217	1549	1812	2018	2177	2301	2399	2483	2563	2651	2756	2891	3066
1	1520	1792	2004	2163	2293	2391	2473	2550	2631	2729	2853	3016	
2	1764	1985	2154	2285	2384	2466	2541	2618	2710	2826	2979		
3	1958	2135	2271	2376	2461	2535	2611	2698	2809	2953			
4	2110	2254	2365	2454	2530	2606	2692	2798	2936				
5	2230	2350	2444	2525	2603	2689	2793	2927					
6	2327	2430	2517	2599	2587	2791	2924						
7	2409	2505	2593	2685	2791	2924							
8	2486	2582	2681	2791	2926								
9	2566	2672	2790	2928									
10	2658	2784	2928										
11	2772	2925											
12	2916												

Table II - Response surface representing least squares means for milk yield of crossbred animals adjusted for calving interval (all data).

Ayrshire proportion (in sixteenths)	Holstein proportion (in sixteenths)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1537	1754	1941	2101	2236	2347	2437	2506	2557	2592	2611	2617	2612
1	1723	1899	2054	2188	2304	2404	2489	2561	2621	2673	2716	2754	
2	1883	2026	2155	2270	2375	2470	2557	2639	2716	2792	2866		
3	2020	2137	2246	2350	2450	2548	2645	2744	2845	2951			
4	2136	2234	2332	2426	2534	2641	2756	2878	3011				
5	2234	2321	2414	2516	2628	2753	2891	3044					
6	2318	2400	2496	2607	2736	2885	3054						
7	2389	2474	2579	2708	2861	3040							
8	2451	2546	2668	2820	3004								
9	2506	2618	2764	2948									
10	2558	2693	2871										
11	2609	2776											
12	2662												

adjusted (Table III). Such reductions in range resulted from the tendency for high producing cows to have long calving intervals, rather than from shorter calving intervals of animals with high percentages of Butana. When grouped by percentage of Holstein breeding (El Amin *et al.*, 1986), calving intervals did not vary much (431 to 436 days), among breed groups, except that F_1 crosses (8/16 Holstein) had shorter calving intervals (405 days). This doubtless represented heterosis for calving interval demonstrated in the F_1 cross. Adjusting for calving interval therefore would affect estimates for milk yield and reduce the range in the estimates.

Data then were separated into two sets. Estimates of the 13 years of lowest yields are in Table III. Separation was made on the basis of the least squares means for years. Such estimates of year effects would be free of variation from other effects included in the mathematical model, except for calving interval (i.e., differences in age, monthly freshening pattern, breed composition and between breed interactions). Our belief was that this identified the years of poorest environmental conditions, and doubtless represented effects of feed, management, climate and other factors. Lowest yields in poor years were pure Butana. Highest yields

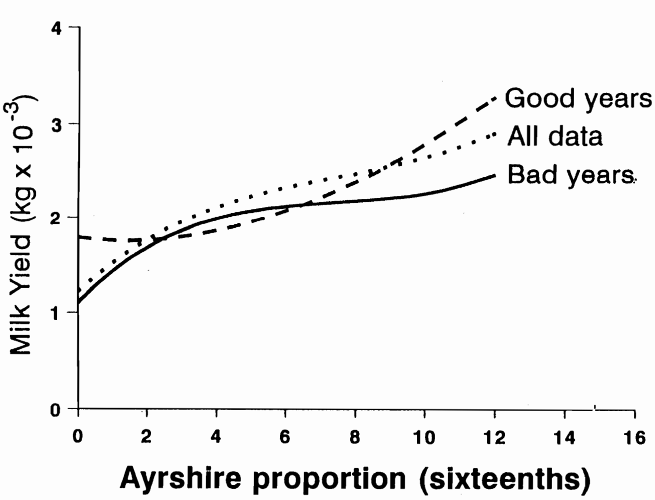

Figure 1 - Effects of upgrading of Butana cows to Ayrshire, overall and in good or bad years.

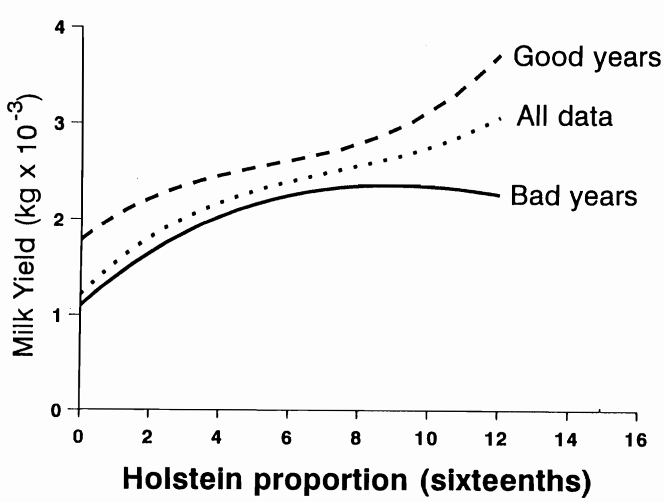

Figure 2 - Effects of upgrading of Butana cows to Holstein overall and in good and bad years.

Table III - Response surface representing least squares means for milk yield of crossbred animals during years of lowest yields (13 yr) not adjusted for calving interval.

Ayrshire proportion (in sixteenths)	Holstein proportion (in sixteenths)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1099	1399	1652	1861	2030	2160	2255	2319	2354	2363	2350	2318	2269
1	1430	1677	1885	2055	2190	2294	2369	2420	2448	2457	2450	2430	
2	1680	1882	2050	2187	2296	2380	2442	2486	2513	2528	2534		
3	1861	2025	2160	2271	2360	2431	2486	2529	2562	2590			
4	1988	2118	2227	2318	2394	2458	2512	2561	2608				
5	2071	2175	2264	2342	2411	2474	2535	2596					
6	2123	2207	2283	2354	2422	2491	2565						
7	2157	2227	2296	2366	2441	2523							
8	2184	2247	2316	2392	2479								
9	2216	2280	2354	2443									
10	2262	2337	2424										
11	2349	2431											
12	2473												

were found in three-breed crossbreds which were 8/16 Holstein, 4/16 Ayrshire and 4/16 Butana. In two breed crosses, highest yields were found in 9/16 Holstein and 12/16 Ayrshires.

Estimates for the 14 years of highest production are in Table IV. In good years highest production was from 12/16 Holstein and 4/16 Butana. Production increased 248 kg with an increase from 0/16 to 1/16 Holstein, and 334 kg from 11/16 to 12/16. Ayrshire crossbreds did not seem to be as desirable as Holstein crossbreds in good years, with very slight decreases in yield from 0/16 to 2/16, but increased yields thereafter to 12/16. The three breed cross which was desirable in poor years (8/16 Holstein, 4/16 Ayrshire, 4/16 Butana), was not as high in good years as either 12/16 Ayrshire or Holstein (3103 kg vs 3288 or 3717 kg).

Table IV - Response surface representing least squares means for milk yields of crossbred animals during years of highest yields (14 years), not adjusted for calving interval.

Ayrshire proportion (in sixteenths)	Holstein proportion (in sixteenths)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1789	2037	2222	2358	2459	2540	2614	2696	2799	2939	3129	3383	3717
1	1758	2029	2233	2385	2499	2590	2671	2757	2862	3000	3186	3433	
2	1761	2051	2271	2436	2561	2659	2744	2831	2935	3068	3246		
3	1796	2101	2335	2511	2642	2744	2831	2917	3016	3141			
4	1861	2180	2423	2606	2742	2846	2931	3011	3103				
5	1954	2283	2534	2721	2859	2961	3041	3114					
6	2075	2411	2666	2855	2991	3088	3161						
7	2221	2562	2819	3006	3136	3226							
8	2392	2734	3989	3171	3295								
9	2586	2926	3176	3351									
10	2801	3136	3379										
11	3036	3364											
12	3288												

Table V - Estimated milk yield (kg) of selected Butana, Ayrshire, and Holstein crossbred dairy cows adjusted or not adjusted for calving interval.

Percentage Butana	Holstein	Ayrshire	Milk yield	
100	0	0	1215[4]	1534[5]
50[1]	50	0	2635	2763
50[2]	50	0	2558	2552
50[1]	0	50	2492	2631
50[2]	0	50	2481	2446
50[3]	25	25	2525	2528
Overall	(all animals)		2508	2508

[1] F_1 Butana * Holstein or Butana * Ayrshire F_1 crossbreds.
[2] Resulting from various combinations, not F_1.
[3] F_2 Butana * Holstein of Butana * Ayrshire F_1 crossbreds.
[4] Not adjusted for calving interval.
[5] Adjusted for calving interval (461 days).

Table VI - Estimates of heterosis[1] for milk yield (kg) of Butana by Holstein or Ayrshire crossbreds.

Crossbred group	Not adjusted[2]	Adjusted
Butana * Holstein		
F_1	2635	2763
Inter se[2]	2558	2552
Difference	77	211
Heterosis (%)	6.0	16.5
Butana * Ayrshire		
F_1	2492	2631
Inter se[2]	2481	2446
Difference	11	185
Heterosis (%)	.9	15.1
Overall	2508	2508

[1] Expressed as twice the difference between F_1 crossbreds and animals resulting from inter se mating.
[2] Resulting from inter se mating of F_1 crossbreds.
[3] Not adjusted or adjusted to average calving interval (461 days).

Performance of selected breed groups is in Table V. Among these groups lowest production was from pure Butana, either adjusted or not adjusted for calving interval. Crosses resulting from mating of pure Butana females with either pure Holstein or Ayrshire sires (F_1 crosses) produced the most milk of the groups shown in the table, whether adjusted ot not adjusted for calving interval. Holstein crosses were slightly superior to Ayrshire crosses. The three breed cross was slightly superior to Ayrshire but not to Holstein crosses.

Estimates of heterosis for the F_1 individuals were obtained by doubling the difference between F_1 performance and that of 8/16 Butana, 8/16 Hosltein or a comparable Ayrshire crossbred group resulting from estimates for inter se mating (F_2 or subsequent), and are shown in Table VI. Effects of adjustment of records for calving interval increased the estimates of the magnitude of heterosis considerably. After adjustment the estimate of heterosis was 211 kg (Holsteins) or 185 kg (Ayrshires), or 16.5 and 15.1%. When not adjusted, comparable estimates were 77 and 11 kg, or 6.0 and 0.9%.

DISCUSSION

The decline in performance from the first to second generation of crossbreds frequently observed is a major problem with making breeding plans for the tropics. Trail and Gregory (1981) suggested that one way of avoiding most of this loss was to mate crossbred cows with bulls of a different (third) breed. The three breed cross was desirable in poor years in the present data. After the second generation, heterosis would be expected to be lost only through inbreeding, and as long as numbers in the population are large, this need not be a problem.

Crossing two crossbred groups (a four breed cross) should be preferable to inter-se mating of a two breed cross (Trail and Gregory, 1981); four good dairy breeds would be needed for this.

Many programs have aimed at producing a 5/8 exotic, 3/8 adapted crossbred populations, i.e. a synthetic breed. This is based partly on experience with synthetic beef breeds such as Santa Gertrudis, where such a plan seemed logical in terms of having a final topcross with a bull selected for high productivity, and partly on the basis of analyses of dairy crossbred data from India (e.g. Katpatal, 1983). The regression of milk yield on breed composition in eighths in that study was maximum at the 5/8 exotic level in that study, but this apparently was an artifact of the regression estimation procedures. Plotting the points discretely, Katpatal (1983) showed that both the 1/2 and 3/4 levels, which had European sires, were superior to the 5/8 level. Review of research from various countries has shown that Holstein, Sahiwal, Jersey and Butana would be excellent breeds for milk production, although Red Dane, Sahiwal, Illawarra and Butana would be nearly as good and would have the advantage of producing animals with a solid deep red coat color. Red Dane-Sahiwal crosses have done very well in southern India (Madsen, 1976).

The value of a synthetic breed produced by inter-se mating of a crossbred population depends on several factors. If the breeding stock is selected under much more favorable conditions than the average producer can provide, the synthetic breed probably would be only slightly more adapted than temperate purebred animals. Selection under realistic field conditions seems important. It has been proposed that, because a crossbred population has greater genetic variability than a pure breed, faster progress can be made by selection in creating a synthetic breed than within established breeds (Trail and Gregory, 1981). In practice this seems unlikely to be true because the established breed usually has far greater numbers of animals from which to select sires, and because of small numbers and greater variation in the progeny of each sire in the synthetic breed. Heterosis accounts for much of the variability in the F_2 generation. Time and money spent on progeny testing might be spent better on producing more generations of animals sired by bulls chosen only by their dam's production. When the dam is not milked, as usual with Brahman cows, relative milk production can be estimated by measuring weight gain in calves (McGlothlen, 1987).

The mystique of having purebred cattle has caused many breeders to limit progress within their herds by using only purebred sires. This would be avoided if a synthetic breed were created. After three or four generations of selection under local conditions, the new synthetic breed can be regarded as a local breed, perhaps nearly as adapted as the original local breed. Then it can be improved by introduction of more exotic breeding, perhaps by mating half of the cows to bulls of high producing pure breeds. Existing synthetic breeds developed in other locations also can be introduced if their production is high or if they carry desired traits. Registry books of a synthetic breed probably should never be closed, which would exclude improvement by importation of superior stock. Synthetic breeds often have been selected more for tick resistance and milk let-down than for production. Under the average (or best) conditions of the present study, however, continued upgrading to at least 3/4 exotic breeding seemed warranted.

ACKNOWLEDGMENTS

Authors wish to acknowledge contributions of Dr. P.J. Hansen, University of Florida, for creating Figure 1 and review of the manuscript.

RESUMO

Foram analisados dados do Sudão, representados por um rebanho estabelecido em 1907 com Butana, uma raça Zebu, cruzado com touros de raças Ayrshire, Holstein, Guernsey e Shorthorn para leite. A média da produção de leite foi 2508 kg; a média do intervalo entre partos foi 461 dias. Análises estatísticas de 4121 registros de lactação de 892 vacas foi realizada pelo método usual de análise de variância dos quadrados mínimos. O modelo matemático incluiu ano, mês e idade ao parto, porcentagem da composição do cruzamento Europeu e interações da composição do cruzamento. O intervalo entre partos foi incluido como uma variável independente em alguns modelos (a variável dependente foi a produção de leite). Todos os animais eram no mínimo 29% Butana.

Os dados cobriram 27 anos; análises adicionais foram realizadas em dois subconjuntos de dados representando os melhores 14 anos e os piores 13 anos. Estimativas de heterose para produção de leite foram 0,9 e 6,0% para F_1 do cruzamento Ayrshire e Holstein para dados não ajustados para o intervalo entre partos, ou 15,1 e 16,5% se ajustados. A produção de leite foi mais alta para cruzamentos Holstein, menores para cruzamentos intermediários Ayrshire, com três raças (Ayrshire, Holstein, Butana).

Obteve-se estimativas de produção de leite para 91 grupos cruzados através da metodologia de resposta de superfície com raças de composição Holstein, Ayrshire e Butana.

Em anos bons, os resultados sugeriram que a produção de leite aumentou para cruzamentos Europeus 12/16 de ambos Holstein ou Ayrshire, embora a produção máxima de leite, quando ajustados para intervalo entre partos, resultou em animais 6/16 Holstein, 6/16 Ayrshire e 4/16 Butana. Em anos pobres, os resultados foram similares; para intervalo entre partos não ajustado e a produção mais alta foi para cruzamentos 8/16 Holstein, 4/16 Ayrshire e 4/16 Butana.

Os resultados sugerem que nas condições ambientais encontradas, mestiçagem de Butana com até no mínimo 12/16 Holstein ou Ayrshire, seria associado com a produção máxima média nos anos bons e com somente um pequeno declínio na produção de leite em anos pobres.

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(Received June 22, 1994)