Reproduction of Cross- and Purebred Friesian Cattle in Northern Thailand with Special Reference to Their Milk Production

P. Pongpiachan*, P. Rodtian[1] and K. Ōta[2]

Department of Animal Science, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200 Thailand

ABSTRACT : Reproductive data, such as numbers of days to the first estrus and A.I. service postpartum, number of days to conception, number of A.I. services required for conception, interval between the first estrus and first A.I. service and the average interval of A.I. service in Thai native-Friesian crossbred and pure Friesian dairy cows, were compiled in the National Dairy Training and Applied Research Institute in Chiang Mai, Thailand. The data were analyzed statistically and the effect of milk production on these reproductive traits was investigated. The reproductive efficiency of purebred cows was obviously inferior when compared with crossbred animals, in spite of special care being given to the purebred only in order to alleviate the effect of a tropical climate and provide better feeding. However, the regression analysis between reproductive and lactational parameters revealed a definite antagonistic effect of lactation on reproduction, especially in the purebred cows, which had a larger amount of milk production and longer lactation period. If these effects of lactation were eliminated, there would be no evident difference in reproductive efficiency between purebred and crossbred cows in the conditions of this study. Among the reproductive parameters examined, the number of days to the first estrus and interval between the first estrus and first A.I. service were less affected by breed difference and the magnitude of lactation than other reasons. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 8 : 1093-1101)***

Key Words : Reproduction, Milk Production, Crossbred, Friesian, Cow, Thailand

INTRODUCTION

The main body of dairy cattle now kept in northern Thailand are crossbreds of various degrees between Thai-native and Friesian cows. We reported on the milk production of such crossbreds, compared with that of pure Friesians, in our previous paper (Pongpiachan et al., 2000) on the basis of past data compiled on 50% and 75% crossbred and purebred Friesian cows, respectively, fed in the National Dairy Training and Applied Research Institute (NDTARI), Livestock Department, Ministry of Agriculture, in Chiang Mai. We analyzed the effect of a tropical climate on their lactations. A similar research was conducted in this study on the reproductive performance of dairy cows kept in the institute.

A lot of work has been done on the antagonistic relationship between milk production and reproductive performance of dairy cattle over many years since the pioneer work of Gaines (1927). The analyses performed on a large scale in recent years were all agreed in recognizing the adverse effect of increased milk yield on the fertility of cows, which was expressed in terms of number of days open, calving interval and so on (Nebel and McGillard, 1993; Lee et al., 1997; Dematawewa and Berger, 1998; Loeffler, et al., 1999, Hansen, 2000; Lucy, 2001). Nevertheless, evaluation to the extent of effect on and interpretation of its possible mechanism was not necessarily consistent among workers. There was a big difference in milk yield between pure Friesians and those crossbred with Thai native cattle in the present study. In order to examine the reproductive performance in each of these breeds, this big discrepancy in milk production and its possible effect on reproduction cannot be ignored. For this reason, only the records of pure- and crossbred Friesian cows, of which data on their reproduction and lactation such as dates of calving, estrus, A.I. service given, confirmation of conception and termination of milking, total milk production and duration of lactation were properly prepared, were selected from files during 1989 to 1995 in NDTARI, and used for this analysis.

The adverse effect of a tropical climate on reproductive performance is also very important when considering dairy farming in Thailand, and this problem was also subjected to analysis in this study. However, it was a little complicated when the effects of several climatic factors were examined in combination with periods affected throughout lactation. Its complexity was increased further by the fact that cooling by water sprinkling and forced ventilation to alleviate the effect of high temperature in the hot season was made in the stall for purebred Friesians, but not in that for crossbreds. In order to avoid excessive cramming in this paper, results of a climatic effect on reproduction analysis are not dealt with here. They will be described in detail, together with other data on the same subject, later on (Pongpiachan et al., 2003).

* Corresponding Author: Petai Pongpiachan. Tel: +66-53-94-4001, Fax: +66-53-94-4666, E-mail: petai@chiangmai.ac.th

[1] National Dairy Training and Applied Research Institute, Department of Livestock Development, Ministry of Agriculture, Chiang Mai 50120, Thailand.

[2] Senior Volunteer of Japan International Cooperation Agency working in Faculty of Agriculture, Chiang Mai University.

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Table 1. Summary of data on lactational and reproductive performances of cross- and purebred Friesian cows

Item[1]	Breed		
	50% Crossbred	75% Crossbred	Purebred
N	5	52	70
Age (days)	2,478.2±284.3^{a}[2]	1,429.3± 77.3^{b}	1,721.7± 39.7^{c}
PAR	4.2± 0.4^{a}	2.3± 0.2^{b}	2.9± 0.1^{c}
CALV[3] (days)	419.7±62.7^{ab} (3)	401.2±11.2^{a} (31)	524.0±25.7^{b} (19)
DRY[3] (days)	110.0±42.0^{a} (3)	151.6±13.9^{a} (31)	190.2±24.0^{a} (19)
PREG[3] (days)	275.0±3.2^{a} (3)	279.6±3.7^{a} (31)	277.5±2.9^{a} (17)
TMP (kg)	3,341.6±569.2^{a}	3,091.1±131.6^{a}	7,779.6±302.6^{b}
DUR (day)	266.8± 38.3^{a}	264.5± 8.3^{a}	347.6± 11.6^{b}
ADMY (kg)	12.3± 1.1^{a}	11.8± 0.5^{a}	22.5± 0.7^{b}
DTFE (day)	56.8± 17.8^{a}	68.2± 4.9^{a}	83.7± 5.9^{a}
DTFAI (day)	79.6± 9.9^{ab}	86.7± 4.2^{a}	110.1± 5.3^{b}
DTC (day)	117.0± 37.1^{a}	139.5± 11.0^{a}	233.4± 15.0^{b}
NAIS	2.6± 0.8^{ab}	2.3± 0.2^{a}	3.6± 0.3^{b}
ETAI (day)[4] (A)	22.8± 9.4^{a}	18.5± 3.7^{a}	26.4± 4.4^{a}
(B)	38.0±1.5^{ab} (3)	40.2±5.2^{a} (24)	55.9±6.1^{b} (33)
IOAI (day)[5] (A)	11.8± 9.3^{ab}	24.4± 3.8^{a}	43.7± 5.2^{b}
(B)	19.6±14.5^{a} (3)	38.4±4.4^{ab} (33)	52.8±6.0^{b} (58)

N=number of lactations in which lactational and reproductive data were recorded. Records from the same cow at different parities are included; PAR= parity; CALV=interval between previous and current calvings; DRY=length of dry period preceding the current calving; PREG=duration of pregnancy preceding the current calving; TMP=total milk production; DUR=duration of lactation; ADMY=average daily milk yield; DTFE=days to the first estrus postpartum; DTFAI=days to the first A.I. service postpartum; DTC=days to conception; NAIS=number of A.I. service required for conception; ETAI= days from the first estrus to the first A.I. service; IOAI=average interval of A.I. service to conception.

Mean±SE. a–c: There was no significant difference between means in the same line having the same alphabet in their superscripts ($p<0.05$; GLM-MEANS/T test).

Numbers of data subjected to the analysis were shown in parentheses. Records of CALV, DRY and PREG were not available in some cows, although those of the former two were not present in primiparous cows of course. In addition, PREG of 2 pure Friesian cows exceeded 400 days and then they were omitted from the calculation of mean and SE of PREG in the breed.

(A) Data of all cows, (B) Data of cows which were inseminated at the first estrus were excluded. Numbers of cows subjected were shown in parentheses.

Data of all cows, (B) Data of cows which conceived by the first A.I. service were excluded. Numbers of cows subjected were shown in parentheses.

MATERIALS AND METHODS

Animals

In the farm at NDTARI, the crossbred between Friesian and Thai natives and the pure Friesian cattle were kept in different herds. Details of these animals and feeding systems for them were described in a previous paper (Pongpiachan et al., 2000). In brief, crossbred cows were kept throughout the whole day in a yard or pasture with small sheds, and fed fresh grass or silage and mineral mix. In addition, a concentrate of ingredients, which were in accordance with the basic NRC standard for dairy cows, was given twice daily at the time of milking (04:30 and 16:00 h), in proportion of a 1 kg diet to 3 kg of milk produced. Purebred cows were kept in a free stall with stockyard. In the stall, big and small fans were fixed on the ceiling of the central feed passageway and operated in the hot-dry and hot-wet seasons (March-May, June-September). Water sprinklers were also set along the passageway at one-meter intervals and worked for 10 minutes in each 30-60 minutes from 08:00 to 23:00 h in hot seasons. The animals were fed with corn silage and a concentrate formulated in accordance with the NRC (1988). The amount of concentrate given to a cow was determined in proportion of her milk yield according to the standard and the diet was given in two installments daily at the time of milking.

Milking records were started from 5 days after calving and stopped 45-60 days before the expected day of the next parturition in pregnant-lactating cows, or at a time when the daily milk yield decreased to below around 5 kg. The total milk yield during a lactation period (TMP) and the duration of lactation (DUR) in number of days from the start to the end of milking were recorded.

The estrous behavior of cows such as bellowing and mounting were monitored by daily routine observation throughout the lactation and subsequent dry periods, and animals suspected of being estrous received further detailed observation on vulva and cervical secretion (Rodtian et al., 1996). Conception was confirmed by rectal palpation around 60 days after the last estrus.

Data collection

Records were collected of age (Age) and parity (PAR) at the current lactation, number of days from previous calving to the current one (CALV), durations of dry period (DRY) and pregnancy (PREG) preceding current calving, TMPs and DURs in previous and current lactations as indicators of lactational performance, and numbers of days from current calving to the first estrus (DTFE), A. I. service (DTFAI) postpartum and to the last A. I. Service, i.e. days onto conception (DTC), and the number of times of A. I. service required for making the cow conceive (NAIS). These data were collected in 5, 52 and 70 lactations in 50% and 75% crossbreds and purebred, respectively, from data files during 1989 to 1995. Because records of the same cow and her successive lactations were included, whole data used for the analysis comprised records in 5 lactations in 2 cows, 52 in 21 and 70 in 52, in 50% and 75% crossbreds and purebred, respectively. The average daily milk yield (ADMY) was calculated by dividing TMP by DUR. The interval between the first estrus and first A.I. service (ETAI), and the average interval of A.I. service until fertile insemination (IOAI) were also calculated as (DTFAI-DTFE) and {(DTC-DTFAI)/(NAIS-1)}, respectively. In these indices, two kinds of intervals were obtained; the intervals for all cows (ETAI (A) and IOAI (A)) and those for cows from which animals were inseminated at the first estrus (ETAI (B)) and animals conceived by the first insemination (IOAI (B)) were excluded.

Statistical analysis

Analyses were performed by the use of SAS (1985) and ORIGIN41 (1991) computer programs as far as proper programs were available. GLM, ANOVA and REG procedures in SAS and NONLINEAR CURVE FITTING in ORIGIN41 were mainly employed. All statistical significances were judged basically at a 5% level. The first, second and third order regressions were checked in the analysis by the REG procedure, and when all partial regression coefficients, as well as the coefficient to the model, were significant and the adjusted R square value increased as the order of regression progressed, the regression of the highest order obtained was adopted. Regressions with positive and negative coefficients of the highest order were noted as positive- and negative-first, second and third order regressions, respectively. In the second and third order regressions, the turning points of the regression equations {y=f(x)}, that is, x values for maximum or minimum value in parabolic and maximum and minimum values in cubic curves, were also calculated.

RESULTS

Reproductive and lactational performance

Data collected in cross- and purebred Friesian cows are summarized in Table 1, although records of milk performance in previous lactations were omitted from the table because of the absence of obvious relationships between them and reproductive performance in current lactation (See the next section). Since only the data of successive lactations in two cows were available in the 50% crossbred, age and parity number were significantly more in this breed than in the other 2 breeds. Data on CALV, DRY and PREG were not recorded in some cows, in addition to the lack of CALV and DRY data in primiparous animals. Although CALV was longer in purebreds than in crossbreds, there were no statistically significant differences in DRY among breeds. No difference in PREG was present among breeds.

Of the reproductive performance in crossbreds, the 50% was superior to the 75% in most of the items examined, i.e., shorter periods in DTFE, DTFAI, DTC, ETAI (B) and IOAI (A and B). The 75% crossbreds were almost comparable to or a little better in values than the 50% in only NAIS and ETAI (A), although no significant differences could be detected between these two breeds because of the small number of available records in the 50%. In comparison with the crossbred, purebred cows required a longer number of days in all DTFE, DTFAI and DTC and a greater number of NAIS. As far as the comparison between the 75% crossbred and purebred was concerned, the differences were statistically significant in all items other than DTFE. Values relating to the interval of recurrence of estrus (ETAI and IOAI, especially in (B)) were also longer in the purebred than in the crossbred (75%). There was no difference in the rate of A.I. service execution at the first estrus, [{N of ETAI (A)}-{N of ETAI (B)}]/{N of ETAI (A)}, between crossbreds (30/57; 52.6%) and purebred (37/70; 52.9%), but the success rate of the first A.I. service, [{N of IOAI (A)}-{N of IOAI (B)}]/{N of IOAI (A)}, was significantly higher in crossbreds (21/57; 36.8%) than in purebreds (12/70; 17.1 %) ($p<0.02$, in χ^2 test).

Effects of factors other than lactational characteristics on the reproductive performance of cows

Regressions of DTFE, DTFAI, DTC, NAIS, ETAI and IOAI on Age, PAR, CALV, DRY and PREG were examined in the 75% crossbred and purebred and throughout all breeds including the 50% crossbred. Regression analysis was not conducted in the 50% crossbred alone because of the small number of samples in this breed. No significant effects of all factors examined were found on any reproductive parameter in the 75% crossbred. In the purebred Friesians, on the other hand, a significant negative-first order regression was observed in DTFAI on Age and DTFE and DTFAI on PAR and the positive-first order was in ETAI on CALV and DRY ($p<0.01$ in all cases). The positive-second order regression was also significant ($p<0.01$) in DTFE on Age, with a minimum value at 1,800 days, i.e. around 5 years, of age. The analysis throughout the 3 breeds revealed that significant regression was restricted to that of Age and PAR, except for the positive-

Table 2. Results of regression analysis on effects of lactation on reproductive traits in 75 % crossbred and purebred Friesian cows (Only significant results are shown)

Reproductive trait[1](Y)	Lactation Item[2](X)	Lactation Range	Regression equation Y=f (X)	p	Turning point[3]
75 % Crossbred (N=52)					
DTFE	DUR	62-380	$Y=2.30\times10^{-3}X^2-1.03X+170.96$	0.014	223.9
DTFAI	TMP	373.8-5,358.4	$Y=-5.93\times10^{-9}X^3+5.35\times10^{-5}X^2-1.45\times10^{-1}X+196.56$	0.007	2,054.7, 3,980.3
	DUR	62-380	$Y=-1.74\times10^{-5}X^3+1.35\times10^{-2}X^2-3.17X+300.78$	0.025	180.2, 337.1
	ADMY	1.3-25.3	$Y=2.95\times10^{-1}X^2-9.97X+160.29$	0.040	16.9
DTC	DUR	62-380	$Y=7.63\times10^{-3}X^2-3.17X+416.60$	<0.001.	207.7
NAIS	TMP	373.8-5,358.4	$Y=4.51\times10^{-4}X+0.86$	0.016	-
	DUR	62-380	$Y=1.17\times10^{-4}X^2-4.61\times10^{-2}X+5.86$	<0.001	197.0
IOAI	DUR	62-380	$Y=1.49\times10^{-3}X^2-5.90\times10^{-1}X+70.66$	0.015	198.0
Purebred (N=70)					
DTFAI	DUR	97-525	$Y=1.09\times10^{-1}X+72.18$	0.045	-
DTC	TMP	1,174.5-15.401.5	$Y=1.98\times10^{-2}X+79.16$	0.001	-
	DUR	97-525	$Y=5.36\times10^{-1}X+46.98$	<0.001	-
NAIS	DUR	97-525	$Y=6.32\times10^{-3}X+1.39$	0.028	-
IOAI	TMP	1,174.5-15.401.5	$Y=7.11\times10^{-3}X-11.59$	<0.001	-
	DUR	97-525	$Y=1.51\times10^{-1}X-8.66$	0.005	-
All breeds (N=127)					
DTFAI	TMP	373.8-15,401.5	$Y=3.95\times10^{-3}X+76.85$	<0.001	-
	DUR	62-525	$Y=1.31\times10^{-1}X+58.54$	<0.001	-
	ADMY	1.3-50.6	$Y=1.08X+80.17$	0.030	-
DTC	TMP	373.8-15,401.5	$Y=2.02\times10^{-2}X+75.76$	<0.001	-
	DUR	62-525	$Y=2.50\times10^{-3}X^2-9.31\times10^{-1}X+216.95$	<0.001	186.2
	ADMY	1.3-50.6	$Y=6.57X+74.14$	<0.001	-
NAIS	TMP	373.8-15,401.5	$Y=2.55\times10^{-4}X+1.55$	<0.001	-
	DUR	62-525	$Y=8.73\times10^{-3}X+0.29$	<0.001	-
	ADMY	1.3-50.6	$Y= 8.39\times10^{-2}X+1.52$	0.001	-
ETAI	DUR	62-525	$Y=6.28\times10^{-2}X+3.56$	0.043	-
IOAI	TMP	373.8-15,401.5	$Y=5.55\times10^{-3}X+2.99$	<0.001	-
	DUR	62-525	$Y=1.62\times10^{-1}X-15.73$	<0.001	-
	ADMY	1.3-50.6	$Y=1.76X+3.45$	<0.001	-

[1, 2] See footnote 1 in Table 1 for abbreviations and/or explanations.

[3] Minimum point of parabolic and minimum and maximum points of cubic curves. They were calculated by using full digits of figures of partial regression coefficients obtained by regression analysis. The values, therefore, are slightly different in some cases from those obtained by the regression equations shown in the table, because only figures of a somewhat restricted number of digits are shown in the equations.

second order regression of ETAI on CALV with a minimum value of 888 days, i.e. around 30 months, of calving interval. In contrast to the result in purebred cows, ETAI became shorter, as CALV became longer in its real range of variation. DTFE regressed on Age and PAR with the negative-first order fashion, while DTC and IOAI regressed on Age and DTC, NAIS and IOAI did on PAR, respectively, with the negative-second order. Age for the maximum values of DTC and IOAI were 1.813 and 4.500 days, around 5 and 12.3 years, respectively. Therefore, both DTC and IOAI increased practically as the age progressed within most of its range in the cattle used. Similarly, the parity numbers for maximum values of DTC, NAIS and IOAI were 2.65, 2.74 and 2.84, respectively. The result indicated that these reproductive parameters increased until around the third calving, but decreased thereafter. Duration of pregnancy did not relate with any reproductive traits in any analysis for individual breed and throughout all breeds.

Relationship between reproductive and lactational performances in cross- and purebred Friesian cows.

Regression analysis was not carried out in the 50% crossbred, as in the previous section. Records in previous lactation had no significant relationship with any reproductive traits during current lactation, except in DTC that regressed on the ADMY in previous lactation in the positive-first order fashion in the analysis throughout all 3 breeds.

In contrast to records in previous lactation, milk production data in current lactation related fairly closely with reproductive traits observed during that period. Significant results obtained by regression analysis are summarized in Table 2, and some examples of regression line and curves are illustrated in Figure 1, which are in

Table 3. Reproductive performance of low milk yield producing purebred Friesian cows

Item[1]		Breed	
		Purebred[3]	Crossbred[6]
N		11	57
TMP (kg)		3,560.5±435.8[a2]	3,113.1±128.1[a]
DUR (day)		211.8±20.2[a]	264.7±8.2[b]
ADMY (kg)		16.5±1.2[a]	11.8±0.5[b]
DTFE (day)		86.3±10.9[a]	67.2±4.7[a]
DTFAI (day)		101.0±12.9[a]	86.1±3.9[a]
DTC (day)		145.4±24.4[a]	137.5±10.5[a]
NAIS (day)		2.6±0.6[a]	2.3±0.2[a]
ETAI (day)	(A)[4]	14.7±8.9[a]	18.9±3.5[a]
	(B)	54.0±19.5[a] (3)	39.4±4.6[a] (27)
IOAI (day)	(A)[5]	15.6±4.9[a]	23.3±3.5[a]
	(B)	28.6±2.6[a] (6)	36.8±4.2[a] (36)

[1, 2, 4, 5] See footnotes of corresponding numbers in Table 1 for abbreviations and/or explanations.

[3] Cows of which TMP was less than 5,358 kg, i.e., the maximum value in 50% and 75% crossbreds.

[6] Combined data of 50% and 75% crossbreds.

composite form with scatter diagrams of individual data.

The pattern of regression was more complicated and then less conspicuous in crossbreds than in pure Friesians and throughout all 3 breeds. Positive-first order regression was obtained in DTC and IOAI on TMP and in all reproductive parameters, except for ETAI, on DUR in pure Friesians, whereas positive-linear regression was found only in NAIS on TMP in the 75% crossbred. The regression pattern was positive-parabolic in DTFE, DTC, NAIS and IOAI on DUR and in DTFAI on ADMY and negative-cubic in DTFAI on TMP and DUR in the 75% crossbred. However, as far as the second and third order regressions on DUR were concerned, inspection of individual data revealed that the regression was mostly due to the presence of four animals, which lactated for only short periods of less than 150 days, but showed exceptionally high values as cows in the breed in one or two reproductive parameters. In addition, TMP of two of these four cows was fairly big in spite of their short DUR, and then their ADMY was much higher than the average value of the breed. If these cases were excluded, values of reproductive parameters would increase linearly along with the elongation of DUR, similarly to the case of the pure Friesian or rising portion of a sigmoid curve (Figure 1 b and c). In the latter case, turning points for minimum values of parabolic and cubic curves seemed to be the lower turning points of the sigmoid.

When data of all three breeds were combined, the relationship between reproductive and lactational traits became simpler. A positive-second order regression was found only in DTC on DUR (Figure 1b). DTFAI, NAIS and IOAI increased linearly according to increases in all TMP, DUR and ADMY and such positive-linear fashion of regression was also found in DTC on TMP (Figure 1a) and

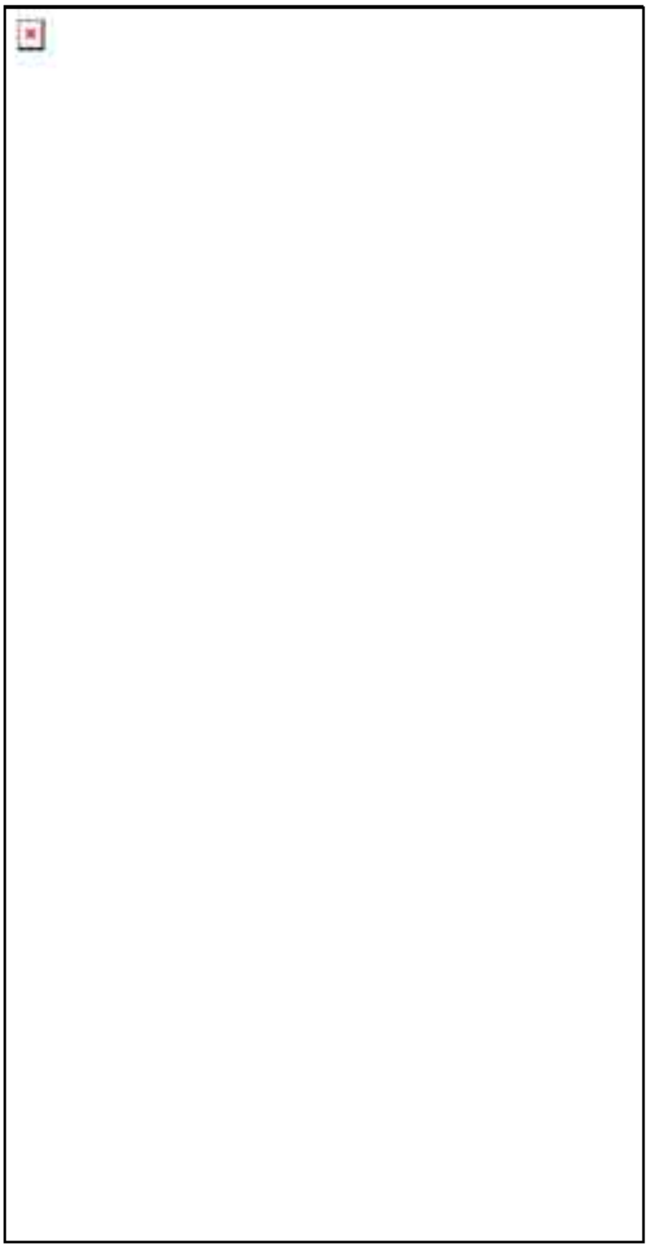

Figure 1. Samples of the first, second and third order regressions of reproductive performance of dairy cows on their lactational parameters. Regression line (the positive-first order regression) and parabolic (the positive-second order) and cubic (the negative-third order) are shown in upper, middle and lower panels, respectively, together with their regression equations and scatter diagrams of individual data in respective cases.
∆ 50% Friesian, ♦ 75% Friesian, o 100% Friesian.

ADMY, and in ETAI on DUR. DTFE did not relate with any lactational parameter.

Comparison of reproductive performance between cross- and purebred Friesian cows in the condition freed of the effect of lactation.

Since all the results above noted indicated that reproductive performance of dairy cows related closely to their lactational records, the performance was compared between cross- and purebreds in conditions where the effect of lactation on them was omitted or at least diminished. Two ways of comparison were conducted. In the first, the residuals of DTC from the regression line of DTC on TMP over all 3 breeds (Figure 1a) were calculated in each breed and compared between them. The least square mean and SE of such residuals were -26.12±44.76, 1.41±13.88 and 0.82±11.96 in 50% and 75% crossbreds and purebred, respectively, and no significant difference in the mean value was found in any combination of breeds. Similar analyses were performed on DTFAI, NAIS and IOAI by the use of their linear regression equations on TMP and DUR, and no significant difference in residuals was found between breeds in any combination of parameters (data not shown). Purebred Friesian cows, whose TMP was in the range of that in crossbred cows, i.e., less than 5,358 kg, the maximum value in all crossbreds, were taken and reproductive traits of these low producing purebred cows were compared with those of crossbreds in the second trial (Table 3). The restriction of TMP was accompanied by the eminent decrease of values in many reproductive items as well as the reduction of DUR and ADMY in pure Friesian cows. The low-grade pure Friesians still had bigger TMP (non-significant) and ADMY ($p<0.05$) than crossbreds, but their DUR was significantly shorter than the latter. In these eleven purebred cows, no significant regression of reproductive parameters on TMP, DUR and ADMY was found. In addition, significant differences were no longer found in all reproductive traits between these low-grade purebred cows and crossbreds, although average values of reproductive parameters, except for ETAI (A) and IOAI (A and B), were still slightly bigger in the purebred.

DISCUSSION

All of the values of reproductive parameters in pure- and crossbred Friesian cattle obtained in this study were almost similar to or at least in the same range as those reported in previous papers on cows in central and northeastern Thailand (Humbert et al., 1990; Chantaraprateep and Humbert, 1993; Harinmirintaranon et al., 1994).

It is generally believed that, in a tropical area, purebred dairy cows of European origin are inferior in their reproductive performance than native cattle of the area and crossbreds (Madsen and Vinter, 1975; McDowell et al., 1976; Fuquay, 1981; McDowell, 1985; Wolfenson et al., 1988; Chantaraprateep and Humbert, 1993). The belief was confirmed as facts in this study. Almost all results shown in Table 1 indicated clearly that the reproductive efficiency of pure Friesian cows decreased markedly in Thailand in comparison with that of their breed fed in temperate zones of the world (Esslemont, 1992) and it was also lower than that of their crossbreds with Thai natives. Pure Friesian cows gave birth with significantly longer intervals after the previous calving (CALV) and/or the termination of previous lactation (DRY). They needed significantly more days after calving to the first A.I. service (DTFAI) and conception (DTC), longer intervals between estrus (ETAI (B) and IOAI (B)) and a greater number of A.I. service to obtain a successful result (NAIS) in comparison with the 50% and 75% crossbreds. This was in spite of special care being given to them only in order to alleviate the influence of the hot climate and raise their nutritional condition. Only the duration to the first estrus (DTFE) did not differ significantly between cross- and purebreds, although the average duration was also longer in the purebred than in either of the two crossbreds.

The lower reproductive performance of European cattle in a tropical area is usually ascribed to its higher susceptibility to heat stress given to animals in hot conditions, and various devices have been made to protect them from the adverse effect of the climate. Frequent ventilation by electric fans and water sprinkling given to the stall for Friesian cows in NDTARI serves this purpose. Although the efficiency of such treatment, together with the effect of a hot climate on the reproduction of cross- and purebred cows, will be analyzed in more detail in the adjoining paper, another problem should be considered. A conflict between reproduction and lactation has long been an important problem in dairy farming (Lucy, 2001). Reproductive efficiency is apt to become worse in cows producing a higher yield of milk, and reproductive disorders are known to occur in a higher incidence in these cows. Negative energy balance, weight loss and decreased body score usually occur in the early stage of lactation because cows cannot ingest enough food to meet the energy requirement for maintenance and milk production during this stage. This nutritional shortage is now recognized as the main cause of delayed restoration of fertility after calving in dairy cattle (Randel, 1990; Nebel and McGillard, 1993; de Vries et al., 1999; Loeffler et al., 1999; de Vries and Veerkamp, 2000). Nebel and McGillard (1993) discussed the possibility of prolonged negative energy balance during early lactation bringing about the decreased secretion of insulin and insulin-like growth factor-I. This hormonal change impaired ovarian function by affecting the hypothalamus to alter the secretion of GnRH from there and then the secretion of gonadotorpin from the pituitary gland on one hand and by rendering ovarian follicles less responsible to gonadtropin stimulation on the other. As for gonadotorpin secretion during lactation, suppression of hypothalamic GnRH release and then that of gonadotropin, especially LH, by milking stimulus should also be considered as a potent factor preventing the fast resumption of ovarian follicular activity after calving (McNeilly, 1988;

McNeilly et al., 1994). In addition, it is also conceivable that a large amount of heat produced accompanying the milk production in the mammary gland reinforces the effect of heat stress on the activity of hypothalamo-pituitary-gonadal axis, especially in tropical conditions. All these problems are enough to warn us that the problem of reproduction in dairy cows, including those of comparison in reproductive performance between breeds with different milk yields, should be considered together with their milk production. Regarding this, only records of pure- and crossbred Friesian cows, of which data on their reproduction and lactation such as dates of calving, estrus, A.I. service given, confirmation of conception and termination of milking and total milk production and duration of lactation were properly prepared, were selected from files during 1989 to 1995 in NDTARI, and used for the analysis in this study.

Prior to the assessing the effect of lactation, other factors affecting reproductive performance of dairy cows were investigated. There were tendencies that DTFE and DTFAI became shorter as the age and parity increased in both the purebred and all breeds, respectively, i.e., the first recurrence of estrus and also the first chance of A.I. service after calving occurred faster as cows became older or had more experience of calving, although the decrease in DTFE was due to the progress of age until 5 years, and the interval became longer in cows older than this age in the purebred. On the other hand, all three parameters concerning conception, DTC, NAIS and IOAI, increased along with the progress of calving number until an age of around three years. DTC and IOAI also increased along with the age in cows younger than 5 years, when a check was carried out over all breeds. This discrepancy in the direction of change against age and parity between DTFE and DTC, NAIS and IOAI may relate to the difference in their relationships to lactational parameters. As described below, reproductive parameters other than DTFE and ETAI increased eminently along with the increase in lactational parameters, TMP and DUR, whereas DTFE did not show any regression on any lactational parameters in the purebred and all three breeds. It was revealed in the previous paper (Pongpiachan et al., 2000) that TMP increased along with the progress of parity until the third calving in all 50% and 75% crossbred and purebred Friesian cows fed at NDTARI. Increases in DTC, NAIS and IOAI, along with the progress of age and parity, therefore, seems to be caused secondarily by the enhancement of milk production due to the progress of age and/or parity. Significant regressions were also obtained in ETAI on the length of calving interval and dry period. Results suggested that recurrence of the estrous cycle became faster in cows having a longer calving interval and dry period prior to calving in the purebred, but the result was in the opposite direction when obtained in data from all breeds, and this discrepancy cannot be explained so easily.

Either TMP or DUR in previous lactations made no significant effect on the value of any reproductive parameter in current lactation, indicating that the influence of a lactation was not carried over to the reproduction in the next lactation. In addition, duration of a dry period prior to calving also did not affect the restoration of ovarian fertility in subsequent lactation. The average length of a dry period, i.e., the period between termination of milking and calving, was more than 5 months in the crossbred and exceeded 6 months in the purebred in the present study. Therefore, the body condition of cows that had been impaired by a large energy consumption for milk production in previous lactation seemed to recover well during these considerably long periods of resting and no effect occurred in the restoration of reproductive activity in the next lactation. In contrast, clear causal relationships were observed between parameters on reproduction and milk production in the same lactation period. In most cases, the relationship was simple enough to be expressed by linear equation. All of TMP, DUR and ADMY are the quantities throughout the whole period of lactation and they do not directly indicate the magnitude of milk production until the time of the first estrus or first A.I. service, or the day of conception. However, the quantities should relate closely to the intensity of milk production during these early stages of lactation and, therefore, the extent of negative energy balance, which occurs in early lactation and is considered the most plausible cause of delayed restoration of reproductive activity after calving. It is conceivable enough that the negative energy balance was more extensive in cows having larger TMP and DUR, and then DTC and other reproductive parameters were worse in such animals. As shown in the purebred and over all three breeds, DTFAI, DTC, NAIS and IOAI increased obviously as TMP and DUR increased, but no significant regressions on these lactational parameters were found in DTFE and ETAI. Although the interval to the first detected estrus was proved to be certainly affected by energy deficit in early lactation (de Vries et al., 1999; de Vries and Veerkamp, 2000), the effect of the deficit may be less profound on the recurrence of the estrous cycle when compared with the restoration of the cow's ability to really conceive by insemination at the estrus.

When these effects of lactation on the restoration of reproductive performance are thought of, a considerable part of the reproductive inferiority of Friesian cows compared with crossbreds may have to be ascribed to the large amount of milk they produce, although the health condition of purebred cows was basically secured by special care given to them against the tropical climate. Two methods were used in this study to eliminate the effect of lactation on reproductive efficiency, and both of them revealed that no significant difference could be found in any of the reproductive parameters between the 50% and 75% crossbreds and pure Friesians, when compared with a condition free of the effect of milk production or among animals with the same range of milk yield. In the crossbred cows, in which maximum and average values of TMP and DUR were 5,360 kg and 3,110 kg and 380 days and 265 days, respectively, the relationships between lactational and reproductive parameters were not so simple, or not so clear-cut as in the purebred, and slightly difficult to understand readily. It was the same in the case of low-grade pure Friesian cows, of which maximum and average TMP and DUR were 5,217 kg and 3,560 kg and 339 days and 212 days, respectively. Between these low-grade purebred cows and crossbred animals, no significant difference was found in any reproductive parameter. These results indicate that, if the effect of a tropical climate is alleviated by forced ventilation and water sprinkling to the extent carried out in this study, even purebred Friesian cows can exhibit reproductive ability originally at the same level as that of crossbred animals, but the larger production of milk in the former breed forces its reproductive performance to become lower. It is said that decreased reproductive efficiency due to increased milk production can be restored to a considerable extent by better feeding, more elaborate health checks and better reproductive management. Greater care over all these points, in addition to protection from the hot climate, may be required in feeding dairy cows in tropical regions in order to keep both productive and reproductive performance higher.

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