Lactation in Cross- and Purebred Friesian Cows in Northern Thailand and Analyses on Effects of Tropical Climate on their Lactation

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ABSTRACT : Data were compiled and statistically analyzed on the lactation of 50% and 75% Thai native-Friesian crossbred and purebred Friesian cows that were fed at a national institute in Chiang Mai, Thailand. More than 30% higher milk production was obtained in the 75% crossbred compared with that in the 50%, but this amount of milk production in the upgraded breed was still about half that of purebred Friesians; 2,138 kg, least squares means during an average lactation period of 279 days in the 50% crossbred, 2,847 kg during 277 days in the 75% crossbred and 5,585 kg during 308 days in the purebred. Environmental stress due to tropical climate was alleviated by the use of electric fans and water sprinklers in the feeding house during the hot season, and improved diet seemed to enable purebred Friesians to keep their ability to produce a milk quantity of more than 6,500 kg per year. This special care was not given to crossbreds and significantly negative correlations were found between daily minimum temperature and humidity during the initial 100 days of lactation and total milk production and average daily milk yield in the 75% crossbreds. However, these correlations were not found in the 50% crossbreds. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 9 : 1316-1322*)

Key Words : Crossbred, Friesian, Cow, Milk Yield, Temperature, Tropical

INTRODUCTION

Crossbreeding of Thai-native cattle with Friesian dairy cows to improve their milk producing ability has been conducted widely in northern as well as other districts in Thailand since the late 1960's. Under the guidance of Chiang Mai AI Research Center, later name the National Dairy Training and Applied Research Institute, Livestock Department, Ministry of Agriculture, the use of such crossbreds for dairy purposes has been propagated rapidly, especially in Chiang Mai and its neighboring districts. As a result, almost all dairy farmers in these districts now feed dairy cows of various degrees of Thai-native and Friesian crossbreeding. As commonly known, Friesian cows have an excellent ability to produce milk, but sometimes they cannot perform fully in tropical areas, owing to their high sensitivity to heat and environmental stresses (McDowell, 1968). Therefore, crossbreeding with native cattle, which is well adapted to a tropical climate, proceeded.

In this paper, initial data were summed up on the lactation of Friesian and their crossbred cows collected at the above mentioned institute over the past 30 years. Then, reliable information was obtained on the relationship between the degree of crossbreeding and lactational performance of cows. By using data on climatic conditions in feeding places the effects of a tropical climate on the lactational performance of cross- and purebred Friesian cows was also analyzed.

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MATERIALS AND METHODS

Animals

All cows used were fed in farms at the National Dairy Training and Applied Research Institute, Livestock Department, Ministry of Agriculture, Chiang Mai, Thailand. Chiang Mai province is located at a latitude of 17-21 °N, longitude 98-99 °E and at an altitude of 310 m. Female cattle of miscellaneous origins, native and crossbreds with American Brahman, were collected from various areas of northern Thailand and bred with pure Friesian bulls by the use of semen supplied from the Artificial Insemination Research Center of the above mentioned department. The F1 crossbreds thus obtained (50% Friesian) were back-crossed with Friesians to obtain 75% Friesian crossbreds. Besides these crossbreds, purebred Friesian cows, imported from Canada in 1990, and their progeny were also subjected to the present survey. Data of 276 and 439 crossbred cows of 50% and 75%, respectively and 148 purebred Friesians were collected from 1970 to 1998 and used for analysis.

Crossbred cows were usually kept throughout the whole day as herds of 20-40 animals in a yard or pasture with small sheds, and fed with fresh grass or silage and mineral mix. They were gathered into stanchion type stalls twice a day for milking (04:30 and 16:00 h) and at the same time given a concentrate formulated from corn grain, rice bran, soybean meal, whole cotton seeds and mineral-vitamin mixture in accordance with the basic NRC feed standard for dairy cows at a proportion of 1 kg diet to 3 kg milk produced. The animals were transferred to open-sided, cement-floored houses with playgrounds when it rained heavily. Neither special ventilation nor cooling facilities were given when housing crossbreds.

Purebred Friesian cows, which were fed in the farm of the institute from 1995, were kept as a herd of 30-40 animals in a free stall with playground. The stall consisted of two feeding/resting areas accompanied by playgrounds with adequate space and a central feed passageway. The building was open-sided, cement-floored and equipped with fans and water sprinklers. Big and small fans, 48 and 24 inches in diameter respectively, were set 5 meters apart alternately on the ceiling of the central feed passageway and operated in the hot-dry and hot-wet seasons (March-September). Water sprinklers were set one meter above the feeding/resting area at intervals of one m along the passageway and used every 30-60 minutes for 10 minutes each time from 08:00 to 23:00 h in hot seasons. The animals were fed with corn silage as rouphage and given the concentrate formulated from the same feedstuffs, as mentioned above, in accordance with the NRC (1988). This standard also applied to the current milk yield, twice a day at the time of milking.

No special care was taken regarding mosquitoes, flies, ticks and other external parasites and no insecticide was used for both cross- and purebred cows. Similar vaccinations for possible diseases were given to all breeds.

Machine milking was performed at 04:30 and 16:00, in stanchions for crossbreds and in a milking parlor for the purebred. From 5 days after parturition, the total milk production during a lactation period (TMP) was obtained from each cow. Milking ceased 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 duration of lactation (DUR) was obtained by calculating the number of days from the start to the end of milking. The average daily milk yield (ADMY) was calculated by dividing the TMP by the DUR for each cow at each parity number. The parity number is the sequential number of parturition that the cow having borne viable offspring. Although estrous behavior of cows was checked by routine observation throughout the lactation and subsequent dry periods, and an A. I. service was given to estrous animals, results are summarized as a separate paper.

Data on climate

The highest, average and lowest values of ambient temperature (℃) and relative humidity (%) supplied daily since 1989 from the Department of Soil Science and Conservation, Faculty of Agriculture, Chiang Mai University were used as climatic data for the analysis in this study, because the places where climatic factors were monitored and animals were kept were near to each other and in the same geographical locations. In addition to the data on temperature and humidity, the temperature-humidity index (THI) of each day was calculated by the use of the average daily temperature and humidity and the equation of Curtis (1983), i.e. THI = $\{0.4\times(DBT+WBT)\}+4.8$, where DBT is the dry bulb temperature (℃) and WBT is the wet bulb temperature (℃) obtained from DBT with relative humidity (%) given.

Statistical analysis

Analyses were carried out by the use of Statgraphics (1985) and SAS (1985) computer programs. For the statistical analysis of the TMP and the ADMY, the following model was used:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkl}$$

Where:

μ = overall mean,
A_i = degree of Friesian gene constitution: 50%, 75% and 100%,
B_j = parity number: 1, 2, 3, and 4+5,
C_k = duration of lactation: 201-233, 234-266, 267-299, 300-332 and 333-365 days,
e_{ijkl} = residual effect.

RESULTS

Total milk production (TMP), average daily milk yield (ADMY), duration of lactation (DUR) and parity number of all cattle examined

Both the TMP and ADMY varied among cattle, with the pattern strongly resembling that of normal distribution in all three breeds examined, although some increases in frequency were observed at the lower end of the distribution curve in the TMP and ADMY of purebreds. Means, SDs and ranges of TMP were 2,009.1±904.1 and 38.4-5,519.0, 2,515.9±1,122.3 and 13.4-5,885.1 and 6,570.3±2,917.0 and 201.5-13,401.5 kg and those of ADMY were 8.0±2.7 and 2.5-15.8, 10.4±3.4 and 1.3-28.0 and 19.0±7.3 and 0.7-50.6 kg/day in 50% (n=276) and 75% (n=439) crossbreds and pure Friesian cows (n=148), respectively.

The DUR also varied with the normal distribution pattern in all breeds. The periods were from 5 to 483 days with a mean and SD of 248.8±72.0, from 5 to 423 days with a mean and SD of 243.4±83.1 in 50% and 75% crossbreds and from 97 to 575 days with a mean and SD of 343.7±84.7 in the purebred. The DUR was generally longer in the purebred than in crossbreds.

The parity number ranged from one to eleven (3.2 ±2.1; mean±SD) and from one to eight (2.3±1.5) in 50% and 75% crossbreds, respectively. The number of cows decreased progressively as the parity number increased and 86.3% and 95.9% of 50% and 75% crossbred cows, respectively, were in their first to fifth lactations. Since purebred Friesian cows were introduced to the institute only 4 years ago, the parity number from them and their progeny did not exceed five (2.4±1.0). In this breed, the number of cows in the second and third lactations were almost equal, and those in the first and then the fourth followed them. Only one cow was in the fifth lactation.

Effects of the degree of crossbreeding, parity number and duration of lactation (DUR) on total milk production (TMP) and average daily milk yield (ADMY) of cows lactating for 201-365 days in their first to fifth lactations

To reduce the influence of the DUR on the assessment of lactational performance, only the data of cows lactating for a restricted period, i.e. from 201 to 365 days, were used in the subsequent analyses and the period was divided into 5 stages with equal length of 33 days, i.e. 201-233, 234-266, 267-299, 300-332 and 333-365 days. Also, to unify the condition of the CALV among the three breeds, the data of crossbred cows were restricted to those in the first to fifth lactations, and then that of cattle in the fourth and fifth lactations were combined to one group to make the number of animals of this group close to that of others in all breeds. Then, the effects of all 3 breeds, the parity number (4 groups) and DUR (5 stages) on the TMP and ADMY were analyzed by three-way factorial anova by using of the general linear model procedure of SAS.

The DUR and parity number of cows thus selected (table 1) were 278.8±129.5 days (mean±SD) and 2.5 ±1.4 in 50% (n=180) and 276.7±43.2 days and 2.2 ±1.2 in 75% (n=308) crossbreds and 307.7±39.7 days and 2.3±1.1 in the purebred (n=85). No significant correlations between the DUR and parity number were recognized in all breeds. Least squares means of TMP and their SEs were 2,137.9±91.1, 2,846.6±69.6 and 5,584.7±132.5 kg and those of ADMY were 7.9±0.3, 10.3±0.2 and 18.1±0.4 kg/day in 50% and 75% crossbreds and the purebred, respectively.

Regarding the effects of breed, the parity number and DUR were highly significant in both the TMP and ADMY. Interactions of breed with the parity number and DUR were also significant as the source of variation in either the TMP or ADMY, indicating that patterns of influence in these factors differed among the two crossbreds and the purebred. Non-existence of a special combination of the parity number and DUR affecting milk production over all breeds was evident by non-significant F values of the interaction between these factors in both the TMP and ADMY, but the significant second-order interaction indicated that the effect of such a combination differed among the three breeds.

Differences in the TMP and ADMY among cows having a different parity number and DUR are shown in figures 1 and 2, respectively. In pure Friesians, an eminently larger TMP and ADMY were obtained as the parity number increased from one to three, but the yields decreased in cows with a more advanced parity number. Milk production from cows in the third lactation was larger than that in the first by 1.81 times in TMP and 1.69 in the ADMY, and the production from cows in the fourth and fifth lactation was less than that in the second. The TMP and ADMY were larger in cows undergone calving more times also in crossbreds, but extents of difference were less than in purebred, i.e. the productions were larger in cattle in the third lactation than those in the first 1.43 and 1.44 times in 50% and only 1.20 times in both TMP and ADMY in 75% crossbreds. In addition, almost the same levels of milk production were obtained from cows in the fourth and fifth lactations. The TMP was larger in cows milked for a longer period, as expected in general, but the results obtained in pure Friesian cows were contrary to some extent. The TMP in cows with a DUR of 234-266 days was less than that in cows with a shorter DUR and almost equal to that in 75% crossbred with the same length of DUR. The ADMY was quite uniformed throughout all DUR groups in crossbreds, while the value was much lower in the DUR group of 234-266 days than that in other groups in purebred. Therefore, the lower ADMY seemed to cause a lesser amount of TMP in the group. Results of a similar nature, although to a lesser extent, were also observed in the group with a DUR of 267-299 days. The rate of increase in the TMP, along with that in the DUR, was obviously higher in pure Friesian than in crossbreds, even when unexpected lower values in the two DUR groups mentioned above were not taken into consideration.

Effect of ambient temperature, humidity and the temperature-humidity index (THI) on the average daily milk yield (ADMY) of cross- and purebred Friesian cows

Daily climatic records together with data on lactation were available on 244 of the cows used in the previous analysis which comprised twenty seven 50% crossbreds, one hundred and eighty two 75% crossbreds and thirty five purebreds.

Daily maximum and minimum temperatures (MAX- and MINT) and humidities (MAX- and MINH) and

Table 1. Summary of data on cattle in mean ± SD (minimum-maximum) used for the analyses

(a) Data on all cows

Breed (% of Friesian gene)	No. of cows	Number of calving	Total milk production (kg)	Average daily milk yield (kg/day)	300 day milk yield (kg)	Duration of lactation (day)
50	276	3.2 ± 2.1	2,009.1 ± 904.1	8.0 ± 2.7	2,440.0 ± 823.5	248.8 ± 72.0
		(1-11)	(38.4-5,519.0)	(2.5-15.8)	(762.5-4,819.0)	(5-483)
75	439	2.3 ± 1.5	2,515.9 ± 1,122.3	10.4 ± 3.4	3,172.0 ± 1,037.0	243.4 ± 83.1
		(1-8)	(13.4-5,885.1)	(1.3-28.0)	(369.5-8,540.0)	(5-423)
100	148	2.4 ± 1.0	6,570.3 ± 2,917.0	19.0 ± 7.3	5,795.0 ± 2,226.5	343.7 ± 84.7
		(1-5)	(201.5-13,401.5)	(0.7-50.6)	(213.5-15,433.0)	(97-575)

(b) Data on cows milked for the period between 201 and 365 days

Breed (% of Friesian gene)	No. of cows	Number of calving	Total milk production (kg)	Average daily milk yield (kg/day)	300 day milk yield (kg)	Duration of lactation (day)
50	180	2.5 ± 1.4*	2,137.9 ± 91.1**	7.9 ± 0.3**	2,409.5 ± 91.5**	278.8 ± 129.5*
75	308	2.2 ± 1.2	2,846.6 ± 69.6	10.3 ± 0.2	3,141.5 ± 61.0	276.7 ± 43.2
100	85	2.3 ± 1.1	5,584.7 ± 132.5	18.1 ± 0.4	5,520.5 ± 122.0	307.7 ± 39.7

* Data in this column expressed in mean ± SD. ** Data in this column expressed in least squares mean ± SE.

the temperature-humidity index (THI) were averaged over the first and second 100 days, i.e. 6-105 and 106-200 days of lactation, respectively, for each cow, and the averages obtained were used as indices of climatic factors which might affect her lactational performance. Regressions of the ADMY on these indices in each breed are shown in table 2. As linear regressions were confirmed by the inspection of scatter diagrams for all indices in all lactational stages and breeds, only the first order of regression coefficients were obtained. Highly significant negative regressions were found between the ADMY and MINT, MINH and THI in the first 100 days in the 75% crossbred, indicating that rises in these values in an earlier stage of lactation caused a decrease in the ADMY in this group of cattle. The portion of variation of ADMY, explained by the climatic conditions (R^2), ranged from 3.9 to 5.5% in this case. Although regressions were not significant in all other analyses, it was noted that regression coefficients of the ADMY on the temperature and the THI indices were all positive in the 50% crossbred. Similar analyses were also completed for the TMP (data not shown). Significant regression was found only on the MAXT in the first and the THI in the second 100 days in the 50% crossbred. The regression was again positive, and with rather high R^2 values (21.3 and 15.8%) in this case. Neither significant regressions of the ADMY and TMP nor high R^2 values were observed on all climatic indices in pure Friesian cows.

DISCUSSION

This paper shows clearly that upgrading Thai native-Friesian 50% to 75% crossbred dairy cattle by backcrossing with purebred Friesians increased the milk production of cows by more than 30% in the TMP. Nevertheless, production from the 75% crossbred was still around half that of pure Friesians (2,138 kg, LS Means during an average DUR of 279 days in 50% and 2,847 kg during 277 days in 75% crossbreds and 5,585 kg during 308 days in the purebred). Results of a similar nature were reported previously at a Thai-Danish Dairy Farm in Central Thailand, where Thai-native and White Zebu cattle were crossed with Red Danish, and milk yields of 1000-1608, 1554-1996 and 1928-3445 kg per lactation were obtained in 50% and 75% crossbreds and pure Red Danish, respectively (Madsen and Vinther, 1975). Generally, lower milk yields, perhaps due to the lower dairy performance of Red Danish compared with Friesian and a higher ratio in the milk yield of crossbreds to that of the purebred (49% in 50 and 67% in 75% crossbreds), are main differences in their results to the ones in this study. McDowell (1968) demonstrated by the analysis of dairy records from Zebu, the crossbreds of Zebu × various European breeds and Friesians under warm-hot climates, that the milk production of cattle was affected more severely as environmental stress was increased by many other factors such as disease, feed quality and quantity, dryness of feeding lot and the availability of shade and cool clean water. He also pointed out that, if these factors were adverse, cows having a higher genetical potential for milk production would receive more damage in their lactation, i.e. cattle with a high proportion of Friesian genes might give a smaller milk yield than those with a lower proportion. In fact, many cases from various tropical areas around the world, in which raising the gene proportion of Friesian or other European dairy cattle in crossbreeding with local breeds or Zebu, brought only a slight increase or more often, decrease in milk yields (McDowell, 1985; Mcdowell et al., 1996). In the case of Madsen and Vinther, purebred Red Danish cows were fed supplementary roughage and concentrates in the same open sheds with grazing pastures as their crossbred herdmates. On the other hand, the purebred Friesian cattle in this study was fed with an improved diet and protected from high temperature stress in the hot season by the use of electric fans and water sprinklers. This special care for purebred cows seemed to be effective in making them exert their full potential adequately and, as a result, a

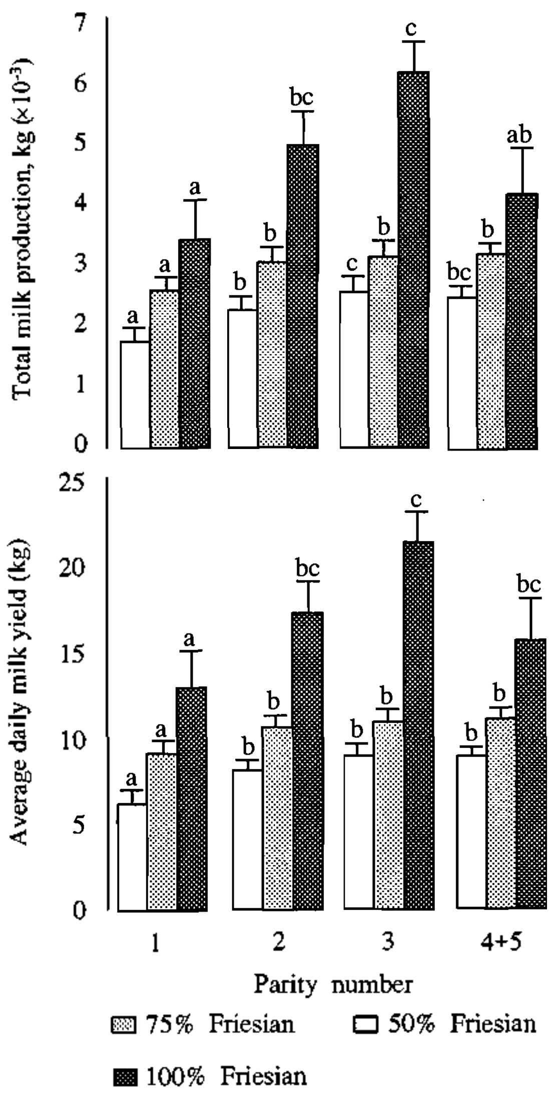

Figure 1. Total milk production and average daily milk yield of 50%, 75% and 100% Friesian cows having a different calving number. Columns and vertical lines represent LS means of respective groups and their upper limits of SEs. □ : 50% (n=57, 42, 31 and 50 for groups of calving number of 1, 2, 3 and 4+5, respectively), ▩ : 75% (n=116, 83, 56, 53), ■ : 100% (n=23, 24, 25, 13). There is no significant difference between LS means of the same breed having the same alphabet in their superscripts (p=0.05).

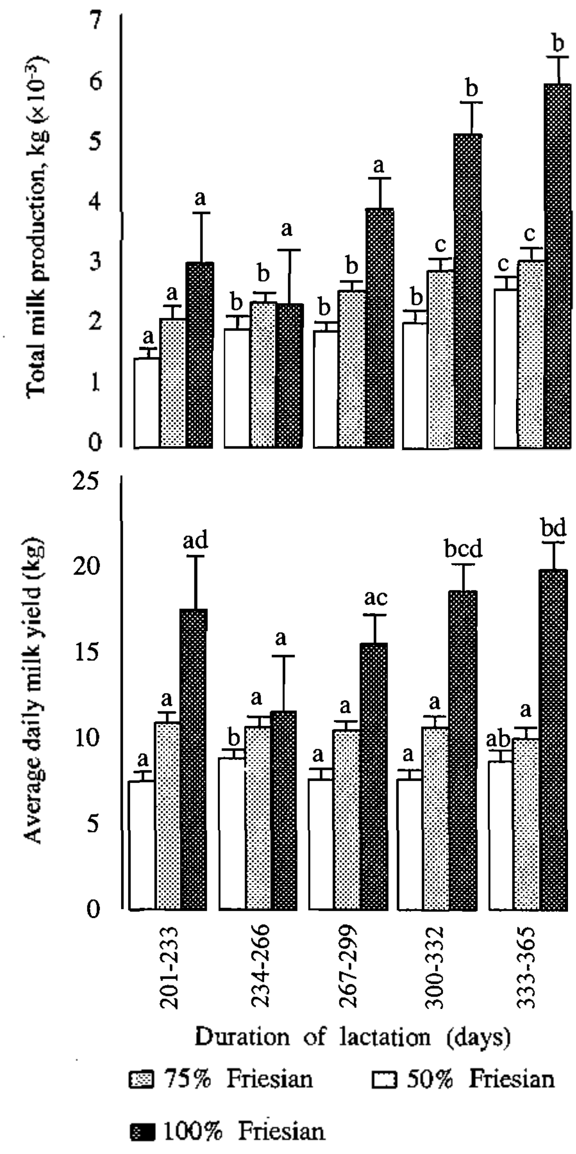

Figure 2. Total milk production and average milk yield of 50%, 75% and 100% Friesian cows having a different duration of lactation. Columns and vertical lines represent LS means of respective groups and their upper limits of SEs. □ : 50% (n=35, 60, 32, 33 and 20 for groups of duration of lactation of 201-233, 234-266, 267-299, 300-332 and 333-365, respectively, ▩ : 75% (n=60, 69, 83, 55, 41), ■ : 100% (n=6, 6, 20, 23, 30). There is no significant difference between LS means of the same breed having the same alphabet in their superscripts (p=0.05).

big difference in milk yield between cross- and purebreds occurred in this study.

TMP is the product of the ADMY and DUR. Upgrading the crossbreds from 50% to 75% in this study increased the ADMY and then the TMP effectively, but not the DUR. In purebred Friesians, on the other hand, a much larger TMP was brought about not only by a higher ADMY, but also a longer DUR than those in crossbreds. Since the DUR related strongly to the TMP, only cattle with a DUR in a restricted range was subjected to more detailed analyses on the TMP and ADMY, and their least squares means were used for the comparison between breeds. The DUR of the thus selected cows, however, was still longer in the purebred than in crossbreds. This longer DUR in pure Friesians may also be ascribed, at least partly, to the effect of the special treatment given to the breed, in addition to its genetical characteristics.

The low TMP in Friesian cows with DURs of 234-266 and 267-299 days, due perhaps to the low ADMY characteristic in the cattle of these DUR groups, attracted attention. The group with a shorter DUR, 201-233 days, contained some animals in which milking was forced to stop at the stage of a constantly high ADMY, but such interruptions were very few in the cows of this group. The Friesian cattle examined in this study consisted of two populations, i.e. original cows imported from Canada in 1990 and their progenies. Madsen and Vinther (1975) found that Red Danish cattle born in Denmark produced a significantly larger amount of milk than their progeny born in Thailand and explained this difference by a carry-over effect from the favorable environment. If a similar phenomenon was present in the Friesian cows of this study, then two different sub-populations having different DURs would be suspected in relation to their generation. The relationship between the parity numbers and DUR was examined, but no significant correlation was found. Both the TMP and ADMY decreased very largely in cows during their fourth and fifth lactation compared with those in the third. A continuous increase in milk yield up to the fifth lactation and a gradual decrease in the subsequent one was reported on Friesian cows fed in Arizona, where, compared to Chiang Mai, the ambient temperature was almost the same or a little lower, and humidity was much lower throughout the year (Ray et al., 1992). The rapid depression in milk production, after a relatively small number of repeat lactations in the herd of this study may indicate that cattle cannot keep the body potential to do the hard work of lactation over so many years under a tropical climate. But the problem of the composition of the herd should be checked again before a conclusion can be drawn.

No climatic effects were observed on the lactation of purebred Friesian cows, again indicating the effectiveness of special care paid to feeding. The time during which water sprinklers were used almost corresponded to that when ambient temperature exceeded 25℃ in the hot season. Roman-Ponce et al. (1977) showed in dairy cows fed in Florida that shade, which was very effective in decreasing ambient temperature and preventing a rise in respiration rate and rectal temperature especially in the afternoon, brought an eminent increase in milk yield. It was very interesting that significantly negative regressions of the ADMY at minimum temperature and humidity, and in the THI during the first 100 days of lactation, were found in the 75% crossbred and that, on the contrary, temperature and humidity tended to affect milk production positively rather than negatively in the 50% crossbred. Dairy cows decreased in their body condition score continuously during the initial stage, e.g. the first 100 days of their lactation (Gallo et al., 1996), indicating that the rapid mobilization of energy from their body reserve for milk production occurred and the energy balance became negative during this stage. In such a condition, animals were said to be sensitive to climatic distress caused by depression of dry matter intake (Taylor et al., 1991; West, 1991; Huber et al., 1994). Ambient temperatures at Chiang Mai rise in the morning, reach maximum in the evening and then decline toward the minimum at around the time of dawn, as in many areas of the world. Then, high values of the minimum temperature means high temperatures during the night. Climatic

Table 2. Regression coefficients of average daily milk yields of 50%, 75% and 100% Friesian dairy cows on climatic factors

	Breed (% of Friesian gene)	Stage of lactation (days)	No. of cows	Regression coefficient	R^2 ($x10^2$)	p
Minimum temperature*	75	6-105	182	-0.141	4.67	<0.01
Minimum humidity*	75	6-105	182	-0.047	5.53	<0.01
Temperature humidity index**	75	6-105	182	-0.220	3.87	<0.01

* Minimum temperature and minimum humidity were the average values of each 6-105 days after calving.

** Temperature-humidity index = {0.4×(DBT+WBT)}+4.8, where DBT is the dry bulb temperature (℃) and WBT is the wet bulb temperature (℃), Curtis (1983).

records at Chiang Mai also showed that variation throughout the year was more eminent at a minimum temperature rather than the maximum; the difference in the maximum temperature between hot and cool seasons was around 2℃, whereas that in the minimum exceeded 5℃. The importance of temperatures during the night when considering the productivity and reproductivity of dairy cattle was pointed out in a review by Fuquay (1981) who showed various direct and indirect evidence: Friesian cows eat more feed at night rather than day-time, and the levels of some blood constituents, including Ca, P, Na, cholesterol and protein, of dairy cows correlate more closely in the summer season with minimum rather than maximum ambient temperatures. Rectal temperature in dairy cows was reported to be higher at mid-night rather than mid-day. Although alleviation of heat stress by air conditioning in the day-time was more effective than at night for lactating dairy cows in Florida, 24-hr air conditioning was more beneficial (Thatcher et al., 1974). Seventy five percent crossbred cows may still keep their ability to resist heat stress during the day-time, but may loose it to some extent when trying to stand high temperatures at night. For the crossbred at this level, as well as for the purebred, some protection from environmental stress must be considered.

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