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Estimation of variance components for production and fertility traits in Northern Thai dairy cattle to define optimal breeding strategies

Dedicated to Prof. Dr. Detlef Leonhard Simon on the occasion of his 75th birthday

Abstract

Milk production in Thailand has been growing into an important agricultural sector, but it still faces numerous difficulties in environmental constraints. The main intention of this study was to identify significant environmental effects on production and fertility traits to give advices for farm management. Additionally, adjusting records for environmental impact is essential to define appropriate models for estimation of variance components and improving selection procedures. The data consists of production and reproduction records and body measurements from 2764 Holstein upgrade cows in 252 farms. With a body weight of 415 kg and a production level of 3668 kg milk Thai Holsteins only reach approximately 60 % of performances of Holsteins in temperate zones. Percentages of Holstein genes of cows and quality of roughage sources showed a certain effect on calving interval and services per conception but not on milk performances. Despite seasonal effects were not very pronounced on milk yield, there was a strong interaction between years and calving seasons. Estimates of variance components applying REML and animal models were in the range as expected, i.e. heritabilities for production traits between 0.34 and 0.37, for fertility lower than 0.03 and for body weight 0.46. Genetic correlations between fertility and production traits were near zero. Economic weights for milk yield and calving interval were derived as first derivation of profit functions and used for selection index calculations. Success in fertility is possible if at least 130 daughters per bull are recorded and if fertility is a part of index sources.

Key Words: Thailand, dairy cattle, variance components, breeding goal, milk yield, fertility

Zusammenfassung

Titel der Arbeit: **Varianzkomponentenschätzung für Produktions- und Fruchtbarkeitsmerkmale zur Definition von Zuchtstrategien in der Milchrindpopulation von Nordthailand**

Milchproduktion hat sich als bedeutender Bestandteil des Thailändischen Agrarsektors mit weiterem Wachstumspotential etabliert. Dennoch gibt es eine Vielzahl von umweltbedingten und managementabhängigen Faktoren, die identifiziert werden müssen, um letztendlich die Milchproduktion zu optimieren sowie bei der Schätzung genetischer Parameter und Zuchtzieldefinitionen die optimale Strategie verfolgen zu können. Das Datenmaterial umfasste Produktions- und Reproduktionsleistungen sowie Körpermessungen von 2764 Holsteinkreuzungen in 252 Betrieben. Mit einem durchschnittlichen Gewicht von 415 kg und Laktationsleistungen von 3668 kg Milch erreichen Thai-Holsteins nur ca. 60 % des Leistungsniveaus von Holsteinkühen in gemäßigten Klimaten. Der HF-Genanteil sowie die Qualität des zugrunde gelegten Rauhfutters hatten entscheidenden Anteil am Fruchtbarkeitserfolg, waren aber nicht signifikant auf die Merkmale der Milchproduktion. Für die untersuchten Produktionsmerkmale stellte sich die Interaktion aus Jahres- und Saisoneffekt als signifikant heraus. Die Schätzung der Varianzkomponenten erfolgte mittels REML unter Anwendung des BLUP-Tiermodells. Die Heritabilitäten lagen im erwarteten Bereich; für Produktionsmerkmale zwischen 0,34 and 0,37, für Fruchtbarkeitsmerkmale unter 0,03 und für Körpergewicht 0,46. Die genetische Korrelation zwischen Milch-kg und Kalbeintervall tendierte gegen Null. Die in der Studie geschätzten genetischen und phänotypischen Parameter wurden verwendet, um ökonomische Gewichte für die Merkmale Milch-kg und Kalbeintervall abzuleiten bzw. um Szenarien zur Selektionsindexberechnung zu modellieren. Nennenswerter Selektionserfolg für Fruchtbarkeitsmerkmale kann nur dann realisiert werden, wenn mindestens 130 Töchter je Bulle geprüft werden und das Fruchtbarkeitsmerkmal als direkte Informationsquelle in den Selektionsindex einbezogen wird.

Schlüsselwörter: Thailand, Milchrind, Varianzkomponentenschätzung, Zuchtzieldefinition, Milchleistung, Fruchtbarkeit

Introduction

Dairy production is going to play an important role in Thailand's agriculture, although the present dairy industry in Thailand is still fairly small but growing. Many milk factories were established in the recent years and an increasing number of farmers have changed from plant to milk production, which was encouraged by the government extension policy since 1962. Currently, milk production in Northern Thailand is mainly performed on small holder farms with about 5 to 10 cows and a very limited area for raising cattle.

In the effort to improve milk production, in the last two decades dairy cattle management has been orientated towards increasing milk yield per animal. Two elements in this process have been the dependence on the breeding policy on Holstein Friesian bull semen from the temperate, continental regions of Europe or North America and the selection of sires based on milk yield only. One concern about such a breeding strategy is the possible existence of an interaction between genotype and environment. In this respect the term environment does not only comprise the physical and climatic factors but also the production and health management, the economic constraints, the prevailing agricultural policies and their combinations. The other concern is on the antagonistic relationships which may exist between milk yield and reproductive traits, which when ignored may result in low reproductive performance and below expected response to selection in the aggregate genotype.

The general aspect of this study was to determine environmental factors on production and reproduction traits of progeny of Holstein sires and to estimate variance components and genetic relationships between such traits with a view to develop the optimum breeding strategy for dairy cattle in Northern Thailand.

Table 1
Descriptive statistics of the investigated production and reproduction records (Deskriptive Statistik der untersuchten Produktions- und Reproduktionsdaten)

Trait	Number of cows	Mean	SD
Milk-kg 100 d	2764	1267	418.9
Milk-kg 305 d	2764	3867	1257.6
Fat-%	391	3.81	0.075
Protein-%	391	3.22	0.028
Total solid-%	391	12.88	0.25
Somatic cells	391	267228	331000
Age of first calving (in month)	1623	28.6	0.07
Services per conception for second parity	1623	2.81	2.4
Days open	1623	129.5	64.3
Calving interval	1623	462.6	98.3
Body condition Score (BCS)	1623	3.32	0.77

Material and Methods

Data for the current study were collected from 252 farms with in average 8,6 cows per farm in three regions within Northern Thailand. The data set comprised 2764 first lactation production and 1623 reproduction records including body conditioning scoring from cows calving between 1997 and 2002. In addition, body measurements and weights in different age groups in a sample of cows were recorded. Tables 1 and 2 give a complete overview of the collected data. Because of the high costs of investigations of milk contents in laboratories, a selected sample of progeny groups was drawn. In this sample, only daughters of sires with 20 offspring and more were considered. The HF – breeding status of cows could be taken directly from the ear tag identification system which in principle has not changed since its introduction in 1966 by the Thai – German dairy cattle project. Apart from these biological traits, economic data in terms of production costs, feed costs (concentrate and roughage), housing costs, labour costs per year and farm-gate milk price per year were collected. The economic data were later used to determine the economic weights for traits that were included in the selection index.

To start with, data were subjected to analysis of variance in order to determine the non genetic factors affecting production, reproduction and conformation traits. The general analysis was done using the GLM procedure of SAS.

Model 1:

$$Y_{ijklm} = \mu + H_i + Y_j + S_k + HF_l + (Y*S)_{jk} + b(AC)_{ijklm} + e_{ijklm}$$

Y_{ijklm}	=	production, fertility and conformation traits of cow m in first parity
μ	=	overall population mean
H_i	=	fixed herd effect
Y_j	=	fixed effect of calving year
S_k	=	fixed effect of season of calving (k=1,2,3)
HF_l	=	fixed effect of percent of Holstein Friesian genes (k=1...5)
$(Y*S)_{jk}$	=	interaction between year and season of calving
$b(AC)_{ijklm}$	=	age at first calving as covariate with b being the linear coefficient
e_{ijklm}	=	random residual effects

In the tropics, there can be a strong impact of coat colour on performances of cows. In this analysis, there was a confounding between the percentage of Holstein Friesian genes and the coat colour indicating higher percentages of white colour with increasing percentages of HF genes. Due to these circumstances, the HF – groups of cows regardless of coat colour were included as fixed effects in our statistical model. Classes of percent HF were created beginning with 50 up to 100 % in increments of 10 %. The seasons of calving were defined as rainy (June – October), winter (November – February) and summer (March – May). Because of practical feasibility, it was not possible to determine weights of all cows using an electronic weighting machine. A random sample of 254 weights was used to calculate regression coefficients from body measurements on body weights. Applying a linear stepwise regression model (SAS, 2001), regression coefficients were 3.73 for heart girth, 3.37 for body length, and 0.95 for rear height, respectively.

To reveal the detailed impact of management practices within farms on production and reproduction traits, farms were characterized by its farm size, number of cows and roughage sources as indicators for feed quality. The following grouping was done (Table 3):

Table 2
Characteristics of body measurements and estimated body weights in different age groups, N = 1672 (Charakteristika der Körpermessungen und Gewichte in verschiedenen Altersklassen, N = 1672)

Age class (years)	Rear height (cm)	Heart girth (cm)	Body length (cm)	Body weight (kg)
< 1	106 ± 2.2	154 ± 4.8	61 ± 2.5	199 ±35.3
1 - < 2	122 ± 0.6	167 ± 1.2	66 ± 0.6	288 ±37.6
2 - < 3	124 ± 0.3	154 ± 0.7	71 ± 0.4	318 ±44.5
≥ 3	126 ± 0.2	182 ± 0.3	76 ± 0.2	426 ±41.8

Table 3
Fixed effects as indicators for management within farms and its grouping for analysis of variance (Fixe Effekte als Indikatoren des Betriebsmanagements und deren Gruppierung für Varianzanalysen)

Group	Farm size (in Rai[1])	No. of cows within farm	Roughage sources (feed quality)
1	≤ 5	≤ 5	Grass and Total Mixed Ration
2	6 -10	6 -10	Grass and by products from vegetables
3	11 -20	11 -20	Grass and rice straw
4	≥ 21	≥ 21	Grass and fermented rice straw

[1)] 1 Rai consists of an area of $1600 m^2$

For analysing the effects of farm size, number of cows in each farm and roughage sources on production, fertility and conformation traits, the model was:

Model 2:

Y_{ijkl} = $\mu + F_i + C_j + R_k + e_{ijkl}$

Y_{ijkl} = production and fertility traits of cow l in first parity
μ = overall population mean
F_i = fixed effect of farm size
C_j = fixed effect of no. of cows per farm
R_k = fixed effect of feed quality
e_{ijkl} = random residual effects

Variance components and genetic correlations between traits then were estimated via REML applying the package VCE (GROENEVELD, 1998) for univariate and bivariate animal models. The genetic structure consists of 346 different sires with in average 4,7 daughters.

The mixed linear model was:

Y_{ijkl} = $\mu + HY_i + S_j + HF_k + a_l + b(AC)_{ijkl} + e_{ijkl}$

Y_{ijkl} = production, reproduction and weight records of cow l in first parity
μ = overall population mean
HY_i = fixed effect of herd calving year
S_j = fixed effect of calving season
HF_k = fixed effect of percent of Holstein Friesian genes
a_l = random additive genetic animal effect
$b(AC)_{ijkl}$ = age at first calving as covariate with b being the linear coefficient
e_{ijkl} = random residual effects

Utilizing the phenotypic values and genetic parameters obtained in the first part of the current study, different breeding scenarios were developed. This was done in order to combine reproduction and production traits in the total merit index. The alternatives included selection based first only on 305-d milk yield and second including calving interval. The last scenario considered milk yield, calving interval and body weight in the index and in the aggregate genotype. Applying the selection index procedure using SIP computer program (WAGENAAR et al., 1995) the standard deviation of the index and the aggregate genotype, the correlation between the index and the aggregate genotype and the expected genetic gain in each trait was calculated and compared for different scenarios. The expected genetic gain was used to identify the optimal breeding strategy for Northern Thailand circumstances.
The economic weight for milk yield was derived as first derivation of the profit function. The profit function was developed from the economic data that were collected in the study as: $P = -m + y(s - a)$; where P is the profit per cow as a function of the level of production y; m is the maintenance cost of cow; y is the lactation milk yield; s is the price per liter of milk; and a is the marginal cost of milk.
The economic weight of milk (w_m) was therefore determined as $w_m = \delta P/\delta y$. The economic values of calving interval (w_c) and body weight (w_b) were calculated based on the relationship of these two traits and milk yield, i.e. what is the cost of having longer than ideal (365 days) calving intervals on milk yield.

Results

In the initial analysis of variance (Model 1), which was aimed at investigating the effect of some important environmental factors on production records, the fixed factors of calving year, calving season and percentage of HF – genes had no significant influence ($p<0.05$) on milk yield in the first 100 days of lactation and over a period of 305 days. Despite these results, there is a strong interaction between years and seasons of calving ($p<0.05$). Least squares means of lactation milk yield by year and season of calving, obtained after the initial analysis of variance, are presented in Table 4. Age at first calving, with was fitted as a covariate in the mixed model, was significant ($p<0.01$) on first lactation milk yield. In all analysis, there is no significant influence of fixed effects on protein and fat contents.

Table 4
LSQ-Means for lactation milk yield (100 and 305 days) of Holstein Friesian upgrade cows for different calving years and calving seasons (LSQ-Mittelwerte für Laktationsleistungen im Merkmal Milch-kg (100 und 305 Tage) von Holstein Friesian Kreuzungskühen für verschiedene Kalbejahre und Kalbesaisons)

Calving Year	Calving Season	Milk-kg 100-d		Milk-kg 305-d	
		Mean	SE	Mean	SE
1997	Winter	1015^b	23.8	3271^b	170.0
	Summer	925^b	23.2	2821^b	154.1
	Rainy	1067^b	25.6	3254^b	162.7
1998	Winter	1090^b	30.0	3325^b	172.3
	Summer	1325^d	34.5	4041^d	210.3
	Rainy	1201^c	31.6	3662^c	186.9
1999	Winter	1184^c	31.8	3612^c	190.9
	Summer	1169^c	31.6	3564^c	187.7
	Rainy	1182^c	31.1	3606^c	188.8
2000	Winter	1169^c	30.4	3567^c	187.5
	Summer	1282^d	33.9	3910^d	201.2

Different superscripts within mean groups indicate significant difference ($p<0.05$), t-test

For fertility traits including services per conception, days of heat return and calving interval, fixed effects of the calving season and the genetic group of the cow characterized by levels of percentages of Holstein genes show significant impact applying analysis of variance (p<0.05). Within all calving years, a distinct advantage could be found for cows calving in the winter season followed by summer calvings. Least square means of services per conception show an advantage within a range from 50 % till 80 % HF genes. But there is a favorable trend between the amount of Holstein Genes and the days of heat return after first insemination resulting in nearly the same calving interval for all genetic groups of cows. Purebred Holstein cows are heavier cows with more body length and heart girth than cows with only 50 % of Holstein genes. Results of genetic groups of cows on fertility and conformation traits are shown in Table 5.

Table 5
LSQ-Means for fertility and conformation traits of Holstein Friesian upgrade cows stratified by groups with different percentages of HF genes (LSQ-Mittelwerte für Fruchtbarkeit und Exterieurmerkmale von Holstein Friesian Kreuzungskühen stratifiziert nach unterschiedlichen HF-Anteilen)

% HF	Services per conception	Days of heat return	Calving interval (days)	Rear height (cm)	Heart girth (cm)	Body length (cm)	Body Weight (kg)
50 – 60	1.23[a]	109.4[b]	447.7[a]	114.6[a]	175.2[c]	74.1	397.1[a]
61 – 70	1.43[a]	115.5[b]	425.3[a]	124.8[b]	181.3[ab]	75.4	427.3[b]
71 – 80	1.10[a]	89.5[a]	437.3[a]	125.1[b]	180.8[ab]	74.6	423.4[b]
81 – 90	2.23[b]	83.5[a]	383.0[b]	125.2[b]	179.5[a]	73.5	414.7[b]
91 – 100	2.14[b]	109.9[b]	445.9[a]	125.9[b]	183.9[b]	74.7	420.3[b]

Different superscripts within mean groups indicate significant difference (p<0.05), t-test

The results of analysis of variance underlying Model 2 can be summarized as follows: Farm size and roughage sources and the number of cows within farms have no significant influence (p<0.05) on production traits. However, there is a distinct dependence between the roughage basis and the success in fertility (p<0.05). Feeding Total Mixed Rations respectively fermented rice straw in addition to fresh grass result in significant better conception rates leading to less days open and an improved calving interval of about one month compared with those farms using untreated straw or various by products from vegetable farming as roughage sources in their feeding rations (Table 6).

Table 6
LSQ-Means for fertility traits of Holstein Friesian upgrade cows stratified by classes of roughage sources (LSQ-Mittelwerte für Fruchtbarkeit von Holstein Friesian Kreuzungskühen stratifiziert nach Klassen von Grundfutterkomponenten)

Roughage source	Days open	Services per conception	days of heat return	gestation length	Calving interval
grass + TMR	128[a]	1.23[a]	107	279	398[a]
grass + by products	155[b]	2.31[b]	110	277	432[b]
grass + rice straw	168[b]	2.22[b]	120	280	423[b]
grass + fermented rice straw	133[a]	1.47[a]	117	278	412[a]

Different superscripts within mean groups indicate significant difference (p<0.05), t-test

After the non-genetic factors that affect production and fertility performances of cows in Northern Thailand were identified and accounted for in the Mixed Model Equations, variance components were estimated. Table 7 displays the results of univariate analysis with respect to additive genetic and residual variances and the resulting heritabilities. Additive genetic variance is the most resemblance between relatives and therefore the major determinant of the observable genetic properties of the population and of the response of the population to selection. The heritability estimates found in this study for production traits are generally in the range of those reported in temperate zones. Heritability estimates and additive genetic variances for fertility traits are as low and for body weight as high as found for dairy populations worldwide.

Table 7
Estimates of variance components and heritability values for some traits of Holstein Friesian upgrade cows in Northern Thailand (Schätzwerte der Varianzkomponenten und Heritabilitäten für einige Merkmale von Holstein Friesian Kreuzungskühen in Nord Thailand)

Trait	σ_A^2	σ_E^2	h^2	s.e.$_h$2
Milk-kg (305 days)	250518.83	461186.83	0.35	0.028
Protein-%	0.041	0.079	0.34	0.027
Fat-%	0.130	0.212	0.38	0.030
Somatic cell Score*)	0.287	2.719	0.10	0.026
Days open	67.97	2124.64	0.03	0.004
Services per conception	0.018	1.67	0.01	0.003
Days of heat return	39.87	1206.22	0.03	0.004
Calving Interval (days)	255.6	9581.70	0.02	0.009
Body weight (kg)	1121.15	1310.64	0.46	0.041

*) SCS = $\log_2$(somatic cells / 100000) + 3

Estimates of genetic and phenotypic correlations between a selective group of productive and reproductive traits and body weight, respectively, were near zero for all bivariate analysis. The phenotypic correlation between first lactation milk yield and calving interval was 0.069 (r_g=0.014) and between milk yield and body weight 0.02 (r_g=0.105). There is also no coherence between calving interval and body weight (r_p=0.035; r_g=0.023). However, due to the limited data basis standard errors for estimates of genetic correlations are substantially high (>0.10).

Table 8
Derivation of economic weights for milk yield and calving interval for Northern Thailand dairy cattle (Ableitung von ökonomischen Gewichten für Milchmenge und Kalbeintervall für Milchkühe in Nord Thailand)

Item / Function	Value	
a) Milk Yield (MY)		
Average Production	3523.47 kg / year * 10 cows = 35234.7 kg / year	
Price of milk	11 Bath / kg	
Maintenance cost per cow	10000 Bath / year	
Marginal cost of milk	Feed + water	= 134750 Bath / year
	Labour	= 28800 Bath / year
	Total	= 163500 Bath / year
Profit margin	163500 Bath / year / 35234.7 kg / year	
		= 4.64 Bath / kg
P = -10000 + 3523.5(11-4.64)		
$w_{my} = \delta P/\delta y$		**= 6.36 Bath / kg**
b) Calving Interval (CI)		
Average CI	462.67 days	
if CI = 365 days, then MY would be:	(365 / 462.67) * 3523.5 kg	= 2779.5 kg
Amount of milk lost		= -744 kg
Value of milk lost	-744 kg * 6.36 Bath / kg	= -4731.8 Bath
w_{CI} = -4731.8 Bath / (462.7 days – 365 days)		**= -48.42 Bath / day**

1 Bath = 0.02122 Euro

For selection criteria, the last part of the study, estimates of phenotypic and genetic parameters for milk yield (305 days), calving interval and body weight obtained in the first part of our study were used. In the past two decades, milk yield has been the most important trait in the breeding goal for dairy cattle in Thailand but the inclusion of fitness traits in the selection index or breeding goal could improve the total productivity compared to when selection is focussed on milk yield only. However, fertility traits such as calving interval or days open have not been given much attention in the choice of imported semen of Holstein sires from North America or Europe. In contrary to Western Europe or North America, body development as an indicator for adaption in forms of body weight plays an important role further on.

Selection index procedures were done in a half sib family structure for different number of daughters per sire. This implies that the performances of daughters are index sources determining the breeding value of the sire. The economic weights for milk yield and calving interval were derived using profit functions on the farm – gate level (Table 8) as described by CHAGUNDA (2000). The economic weight for body weight (w_{bw}=0.81 Bath / kg) was taken from literature.

Table 9
Correlation between index and aggregate genotype (r_{TI}) and selection response from one round of selection for different breeding scenarios. (Korrelation zwischen Zuchtwert und Index (r_{TI}) und Selektionserfolg einer Selektionsrunde für verschiedene Züchtungsstrategien)

Traits in…					Selection response		
Index sources	Breeding goal	Scenario	No. of Daught.	r_{TI}	MY (kg)	CI (days)	BW (kg)
MY	MY + CI + BW	A1	6	.58	449.4	0.13	2.20
		A2	70	.90	693.8	0.19	3.39
		A3	130	.93	715.5	0.20	3.50
MY + CI	MY + CI + BW	B1	6	.59	448.4	-0.23	2.18
		B2	70	.92	686.5	-1.14	3.29
		B3	130	.95	704.9	-1.62	3.36
MY + CI + BW	MY + CI + BW	C1	6	.59	449.8	-0.22	3.82
		C2	70	.92	686.5	-1.14	3.88
		C3	130	.95	704.9	-1.62	3.79

The intention of Northern Thailand milk producers is to develop an independent breeding program as described by SKJERVOLD and LANGHOLZ (1964). In addition to the optimum weights of traits included in the selection index the question raises how to define the structure of the breeding program. The Northern Thai dairy population is characterized by a total number of 10000 milking cows and heifers under artificial insemination. In the main, there are two breeding objectives in discussion, a young bull program in which 90 percent of the inseminations are done by test bulls and a proven bull program in which the part of the test bull inseminations decreased to 50 percent. If the number of test bulls is set to be constant, in a young bull program there will be result approximately 70 daughters from test bulls and in a proven bull program 130 daughters, respectively. The present Northern Thailand breeding strategy is characterized by an average value of only six daughters per young bull. In the aim to take different percentages of test bull inseminations in consideration, selection index calculations were done stratified by different sizes of progeny groups per young bull (Table 9). Selection intensity for calculating selection response was assumed to 1 for all traits.

Discussion

Impact of environmental effects

With an average production level of 3668 kg milk per lactation (305 days) the actual performance of Northern Thai dairy cattle only reaches one half of the production level of Holstein cows in temperate zones indicating essential feeding and management reserves despite the depressing effect of the humid and hot tropical environment. The milk contents (3.85 % fat, 3.15 % protein) are slight below performances of Holsteins in Western Europe or North America mainly due to environmental effects. In our analysis, the genetic group of the cow expressed in percentages of Holstein genes beginning with 50 % up to 100 % has no significant influence on milk performances. In contrary, REODECHA (2002) reported that there is a wide range of milk producing ability from 7 –8 kg to over 20 kg per cow and day mainly depending on the proportion of Holstein Friesian genes. But starting his analysis with 62.5 % HF proportions, an increase in Holstein genes leads in diminishing returns in response of production. Another explanation for our results could be that the positive effect of Holstein gene proportions on milk yield is superposed by the negative effect of higher percentages of white colour. Cows belonging to the lowest HF – class (50 – 60 % Holstein genes) have in average 14.3 % of white colour, cows in the highest HF – class (< 90 % Holstein genes) in contrary 36.6 % of white colour. However, there has been a preference in the past for selecting cows with limited areas of white, because of the fear of skin cancer and its negative influences on performances of cows.

We found a strong dependence between milk yield and the interaction of calving season and calving years. In the summer season 1997, milk yield was significantly lower compared with rainy and winter month but in 1998, there is an advantage for cows calving in the summer period. Especially in Northern Thailand within seasons, the climate can be very variable because of changing Monsun winds. And even in the cold season from October until February, temperature decreases only to levels of 30 degrees in average which is not the optimum for Holstein cows favouring temperatures between 25°F and 77°F (KEOWN, 1991). He reported that heat stress in dairy cattle is one of the leading causes of decreased production and fertility. At 30° C or above, one can usually notice a dramatic decrease in milk production ranging from 3 percent to 20 percent. Some heat stress is unavoidable, but effects can be minimized if certain management practices are followed. Humidity also plays a significant part in heat stress. The danger occurs as the temperature nears 100° F and 50 percent humidity. The lethal range for cattle is 100° F and 80 percent humidity (KEOWN and GRANT, 1991). As was pointed out by JOHNSON (1994) the major climatic variables directly affecting livestock are temperature, humidity, air movement and radiation. In continuing to establish the course for the declining milk yield over years, a temperature – humidity index (THI), an index that combines the temperature and humidity effects in order to measure heat stress, was used in several studies to investigate the direct climatic effects on milk yield. In general, there is a drop of 0.26 kg / day in milk for each 1°F increase in THI and similarly a decrease in 0.23 kg / day in hay intake for each THI increase. The effect of heat stress on changes in body weight, milk production and services per conception in Holstein, Jersey and Australian Milking Zebu Cows was carried out by SKRIKANDAKUMAR and JOHNSON (2004) showing a significantly different breed x treatment interaction for production

traits. The THI during the cooler month of December was 72 and THI increased to 93 in July. This explains an average daily milk production of the Holstein cows significantly higher than that of Jerseys and Australian Milking Zebus only in December.
In an experimental analysis conducted in Thai dairy cattle (BOONBRAHM et al., 2004a) the impact of additional environmental effects like milking methods on production was investigated. Machine milking cows had a significantly higher daily saleable milk production compared with hand milking. Lactation milk yield was significantly higher for cows allowing restricted suckling of calves until 84 days postpartum than artificial rearing.
Cattle will automatically reduce their feed intake during hot weather. Typically, early lactation cows are most swiftly and severely affected. This decreased forage intake alters the composition of the rumen and leads to acidosis and reduced fat content of milk. If cows reduce their intake during heat stress, more nutrients need to be packed into a smaller volume of feed. In our study, improved roughage quality in terms of fermented rice straw leads to higher milk yield (3731.2 vs 3674.5), protein contents (3.22 vs 3.17) and fat contents (3.87 vs 3.80) compared with unfermented rice straw, but not statistical significant ($p<0.05$). But we found a significant difference in fertility traits for different feeding strategies. There is an obvious disadvantage of feeding unfermented rice straw on days open, calving interval, days of heat return and services per conception in comparison to fermented roughages or TMR, respectively.
Despite climatic effects and roughage sources, the influence of calf rearing methods on fertility and body weight was discussed by BOONBRAHM et al. (2004b). They found out in experiments that restricted suckling of calves compared with bucket rearing increases days open significantly. In our study in retrospect, information of calf rearing practices was not available. Nevertheless, our differences found in fertility traits due to roughage sources should be interpreted stable because feeding constraints describe farm management very well and explain a great amount of total variability.

Genetic parameters

There have been numerous papers reporting heritability estimates of milk yield and related traits in Thailand area. The estimates ranged from 0.05 to 0.50 depending on type size of populations as well as the models employed. The two most recent reports involving relatively large data sets including more than 20000 cows were analysed by HIMARAT et al. (2000) and TOPANURAK et al. (2001). HIMARAT et al. (2000) estimated a heritability of 0.25 for milk yield from a large commercial herd characterized by average nutrition and farm management. TOPANURAK et al. (2001), however, obtained the data from smallholder farms. Heritability was 0.19 for milk yield. Heritability estimates for milk yield under small farm conditions estimated by KUHA (1999) and KANLOUNG et al. (1999) were remarkably high (0.55 and 0.53, respectively). These two studies are likely to have overestimated additive genetic variances. In a more recent study using 12505 monthly test day records of 921 first lactation purebred and crossbred cows, heritability was 0.45 for milk yield (KOONAWOOTRIRON et al., 2003). Heritability estimate for SCS in our data was identical with results found by IMBAYARWO-CHIKOSI et al. (2001) in Zimbabwean Holstein-Friesian cattle.

The genetic and phenotypic correlations between productive and reproductive traits generally tends to a lesser extent in magnitude with those reported in literature. For example, REGE (1991) reported a phenotypic correlation of 0.108 between milk yield and calving interval in Kenya. Genetic correlations in Korea (MOON, 1994) between 305 day corrected milk and calving interval ranged from 0.15 to 0.21. For studies in Thailand, no further references analysing fertility from so called index cards are published. Since a few years, artificial insemination is consistently applied in dairy cattle breeding with index cards kept on each farm and e.g. in Northern Thailand, 98% of the dairy farmers are incorporated in dairy cooperatives using and supporting such services.

Economic weights and breeding strategies

The market demand in Thailand is aligned on milk volume and payment is based on the same. Therefore, the economic weight for milk yield that was established in this study does not reflect any milk components other than milk volume. Using the price function derivate approach, the economic weight for milk yield was 6.36 Bath / kg (=0.13 € / kg) and for calving interval –48.42 Bath / day (= -1.03 € / day). The economic weights for milk yield are certainly different from those calculated in Europe, where there is a quota system for milk and fat and protein percentage plays an important role. For example REINSCH (1993) calculated economic weights for milk yield in first lactation of 0.0045 € / kg for dual purpose cattle. The results presented by MACK (1996) for the Holstein breed were 0.095 € / kg milk and –1.025 € / day increasing in calving interval.

Focussing on results of selection index calculations, there is only a minimal decrease in the expected genetic gain in milk yield after introduction of calving interval in the selection criteria. The inclusion of body weight in the index increases the selection response for body weight about 14.4 % and 17.9 % compared with situations selecting for milk yield and milk yield plus calving interval, respectively. In opposition to the actual situation with in average 6 daughters per bull in Thailand, an self-contained breeding program with 130 daughters per bull can nearly reduplicate selection response in milk yield. This raises the question if breeding values of Holstein bulls based on daughter information in North America or Europe are appropriate for the Northern Thai situation or if there are remarkable genotype by environment interactions. Further studies should investigate such topics. One possibility to provide evidence for possible genotype by environment interactions is based on the estimation of genetic correlations between traits measured in two different environments (FALCONER, 1989). An overview of genetic correlations for protein yield in different countries or production systems is published by KÖNIG (2001) indicating genotype by environment interactions for performances between substantial different environments. If there are indications for genotype by environment interactions, an independent Northern Thailand dairy cattle breeding program should be established. Model calculations concerning the comparison between a young bull and a proven bull program focussed on selection response in the whole population and net returns using formulas derived by SKJERVOLD and LANGHOLZ (1964) are outlined by CHONGKASIKIT (2003).

The most serious constraint is, however, that the extensive milk recording schemes which support dairy cattle breeding programs in many temperate countries are almost

non-existent in the tropics. In this situation, one realistic approach to improvement through selection is to start with a single nucleus herd as first suggested by HINKS (1978) and recently recommended by Chagunda et al. (1998) for dairy cattle in Malawi. SYRSTAD and RUANE (1998) compared programs for a closed herd of 500 cows. The alternative which assumed no progeny testing, i.e. selection of bulls on pedigree information only, gave the fastest genetic improvement. By distributing breeding bulls from the herd to the outside population the genetic progress can be disseminated by a time lag of about two generations. Additionally problems can be inbreeding and a reduction in variance due to gametic disequilibrium (COLLEAU, 1985) and the possibility of gentotype by environment interaction if nucleus and outside environments are really different from each other. The estimate for the genetic correlation between protein yield in the first lactation in the field and the second lactation on station for a sample of potential bull dams was only 0.64 in an analysis conducted by SWALVE et al. (1993) in German Holstein. A young sire programme operated as an open nucleus was elaborated by DEMPFLE and JAITNER (1998) for N'Dama cattle in West Africa. The young sire programme proved as efficient as a half-sib programme. The breeding programme annually utilizes 6 breeding bulls and 400 adult breeding females. The 200 breeding bulls and females are kept in one herd. After three years, selection based on estimated breeding values for daily weight gain (from 15 to 36 month) and milk production takes place. The best males are chosen to replace the breeding males, whereas most of females are allowed to breed in order to be performance tested with respect to milk yield.
There are manifold alternatives describing breeding programs, but the above discussed attempt to establish progeny breeding programs including more than 100 daughters per young bull will be the best way, in particular for improving traits with low heritabilities like fertility.

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