

Characterization of Lactation Patterns and Milk Yield in a Multibreed Dairy Cattle Population in the Central Thailand

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ABSTRACT

Patterns for five 5 lactation traits: initial yield (IY), peak yield (PY), days to peak (DTP), persistency (PST) and 305-d milk yield (MY) were studied in a multibreed population in Central Thailand using first-lactation, monthly test-day records collected on 108 farms from 1998 to 2006. Breed groups were BG1 (purebred H), BG2 ($0.9687 \leq H < 1.00$), BG3 ($0.9375 \leq H < 0.9687$), BG4 ($0.875 \leq H < 0.9375$) and BG5 ($0.50 \leq H < 0.875$). The model for each trait included the fixed effects of herd-year-season, calving age and breed group. Random effects were cow and residual. Covariance components were estimated using an average information restricted maximum likelihood procedure, and were subsequently used to calculate the heritabilities and genetic correlations. Least square means ranged from 14.16 ± 0.71 kg (BG5) to 16.04 ± 0.66 kg (BG4) for IY, 18.23 ± 0.55 kg (BG5) to 19.84 ± 0.51 kg (BG4) for PY, 36.51 ± 3.78 d (BG4) to 52.04 ± 9.74 d (BG1) for DTP, 6.45 ± 0.24 (BG1) to 6.71 ± 0.11 (BG3) for PST, and $4,083.74 \pm 103.50$ kg (BG5) to $4,317.15 \pm 111.56$ kg (BG3) for MY. Breed group differences were non-significant. Heritability estimates were 0.23 ± 0.18 for IY, 0.20 ± 0.18 for PY, 0.52 ± 0.28 for DTP, 0.21 ± 0.19 for PST, and 0.43 ± 0.24 for MY. Genetic correlations between MY and IY, PY, DTP and PST were 0.40 ± 0.45 , 0.62 ± 0.30 , 0.36 ± 0.33 , and 0.56 ± 0.39 , respectively. These results suggested that PY and PST could be improved resulting in higher MY under the environmental conditions of Central Thailand.

Key words: dairy, multibreed, tropic, lactation pattern, milk, genetic

INTRODUCTION

A lactation pattern for an individual cow starts after calving (initial yield; IY), milk production normally increases from the beginning to the peak of lactation (peak yield; PY) in 60 to 90 days (days to peak; DTP), and then it decreases (persistency; PST) until the cow is dried off (Wood, 1967). Dairy cows that have higher IY, higher PY

and more ability to continue to produce milk at near peak levels throughout the lactation are expected to have higher milk yields per lactation.

Lactation patterns could be different among individuals or groups of cows, and cows that produce similar amounts of milk may not necessarily have similar lactation patterns (Wood, 1969; Grossman *et al.*, 1986; Koonawootrittriron *et al.*, 2001). The lactation pattern (IY, PY, DTP,

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and PST) and milk yield could be influenced by genetic effects (Ferris *et al.*, 1985; Rekaya *et al.*, 2000) and non-genetic effects (management, environmental conditions, age, parity and health status, Tekerli *et al.*, 2000; Rekik *et al.*, 2003). Thus, accurate knowledge of lactation patterns of individual or groups of animals is necessary to improve the efficiency of management and selection in dairy cattle operations.

Thailand is a tropical country situated between 5°37' and 20°27' north and 97°22' and 105°37' east. Weather in Thailand is influenced by tropical monsoons, and it generally has high temperature and humidity (Thai Meteorological Department, 2004). The most important dairy production area is the central region of Thailand. In 2005, dairy farmers in this region produced 805,083 kg of raw milk per day, equivalent to 66% of the milk production for the whole country (Department of Livestock Development, 2006). Currently, the dairy cattle population in Central Thailand is composed of purebred Holstein (H) and a high percentage of H animals with various fractions of other *Bos taurus* (Brown Swiss, Jersey, Red Dane) and *Bos indicus* (Brahman, Red Sindhi, Sahiwal) breeds (O). Parents in this population are chosen from H, crossbred H and O breed groups, resulting in a multibreed population composed of animals with a variety of breed compositions (Dairy Farming Promotion Organization, 2007). This multibreed population structure is largely a consequence of a national effort encouraged by the Thai government to upgrade to H as a means of increasing milk production under Thai environmental conditions.

Genetic evaluations for milk yield, fat yield and fat percentage in Central Thailand have been conducted by Kasetsart University in cooperation with the Dairy Farming Promotion Organization (DPO) since 1996 (Dairy Farming Promotion Organization, 2007). To further improve management and the ability to select animals suitable for Thai tropical conditions, a

more complete understanding of lactation patterns (IY, PY, DTP and PST) and their association with milk production (MY) is needed. Thus, the objective of this research was to study the patterns of five lactation traits: IY, PY, DTP, PST and MY in five breed groups in a Holstein-Other breeds (HO) multibreed population in the central region of Thailand.

MATERIALS AND METHODS

Animals and data

The data consisted of 5,713 monthly, test-day milk records from 520 first lactation cows collected from 1998 to 2006 on 108 farms located in Central Thailand. This dataset was gathered by the Dairy Farming Promotion Organization (DPO). Cows were the progeny of 144 sires and 475 dams. The main breed represented was Holstein (H). Crossbred H cows constituted the majority of the population (96%). All animals in this population were more than 50% H. Considering the H fraction of individual cows and the upgrading scheme that was practiced in Thailand, breed groups (additive genetic groups) in this multibreed dairy population were classified as BG1 (Holstein; H), BG2 ($0.9687 \leq H < 1.00$), BG3 ($0.9375 \leq H < 0.9687$), BG4 ($0.875 \leq H < 0.9375$) and BG5 ($0.50 \leq H < 0.875$).

Climate, nutrition and management

The weather in Central Thailand is influenced by tropical monsoons (the southwest monsoon occurring from May to October and the northeast monsoon occurring from October to February). Daily temperatures in this region range from 19° to 36°C, relative humidity ranges from 48 to 94% and rainfall is approximately 1,232 mm per year. (Thai Meteorological Department, 2004). Season were winter (November to February; cool and dry), summer (March to June; hot and dry) and a rainy season (July to October; hot and humid).

Dairy farmers fed their cows with grass and concentrate. Cows received fresh grass (direct grazing or cut and carry; 30 to 40 kg/d) from the farmer's own land (90% of the farmers) or from public grazing areas (small holders) and concentrate (12 to 15 kg/d, or 1 kg of concentrate for 2 kg of milk). Pasture grasses were Guinea (*Penicum maximum*), Ruzi (*Brachiaria ruziziensis*), Napier (*Pennisetum purpureum*) and Para (*Brachiaria mutica*). Farmers mixed grasses with legumes such as Verano stylo (*Stylosanthes hamata* cv. Verano), Thapra stylo (*Stylosanthes guianensis*) and Leucaena (*Leucaena leucocephala*) to improve their nutritional value. Mixed pasture composition was roughly 90% grasses and 10% legumes, because grasses grow faster than legumes in this area. When fresh grass decreased in the dry season, rice straw, urea-treated rice straw, crop residues and agricultural byproducts were used as sources of fiber. Concentrate was either produced by farmers or bought from cooperatives and local companies. The main ingredients of concentrate mixtures produced by farmers were cassava, broken rice, cracked corn, soybean meal, cotton seed and molasses. Mineral supplements were available throughout the year.

All cows in this population were kept in open barns. Some dairy farmers (less than 10%) used fans to reduce heat stress of their cows when temperatures were too high. Farmers milked cows twice a day. The first milking was early in the morning (4 to 6 am) and the second milking was in the afternoon (3 to 5 pm). A bucket-type system was used for milking in all farms. Hand milking was used only for cows with mastitis. Farmers sent their milk to a cooperative or milk collection center after each milking. Healthy cows were taken to pasture after the first milking and then they were brought back to the barns before the second milking.

All cows were detected for heat and they were bred year round by artificial insemination.

Sires were chosen primarily based on semen availability, semen price and by their genetic ability with respect to economically important traits (e.g. milk yield, age at first calving, conformation). Reasons for culling cows were mainly health and reproductive problems.

Estimation of lactation patterns and milk yield

A gamma function (Wood, 1967) was used to describe the lactation patterns in this population:

$$y_t = at^{b-1}e^{-ct},$$

where:

y_t is daily yield at the t time,

a , b , and c are the constants.

The constant a is a scale factor associated with average daily yield at the start of the lactation, b is associated to the increase in milk before peak yield, and c is related to the decrease in milk after peak yield. Thus, initial yield (IY) was defined to be equal to a , peak yield (PY) was estimated equal to $a(b/c)^{b-1}$, days to peak (DTP) was estimated as b/c , persistency (PST) was computed as $c^{-(b+1)}$ and accumulated 305-d milk yield (MY) was calculated as the sum of monthly test-day milk estimates (y_t) for an individual cow.

To determine the value of the constants a , b and c for a particular cow, the gamma function was transformed logarithmically into a linear form, $\ln(y_t) = \ln(a) + b \ln(t) - c(t)$ and then fitted to monthly test-day milk records for individual cows using Proc REG in SAS (SAS, 2003). Then, estimates of the constants a , b and c were used to calculate IY, PY, DTP, PST and MY for every cow in the population. Descriptive statistics for the traits are shown in Table 1.

Data analyses

Preliminary data analyses found that the heterosis effect, $1/2$ (HO + OH – HH – OO), was not significant in this dairy dataset. Thus, the model for IY, PY, DTP, PST and MY included the fixed effects of herd-year-season, calving age and

Table 1 Descriptive statistics for initial yield, peak yield, day to peak, persistency and milk yield of cows.

Trait	No.	Means	SD	Minimum	Maximum
Initial yield (kg)	520	14.90	6.22	3.30	44.90
Peak yield (kg)	520	18.58	5.67	8.00	44.90
Days to peak (day)	520	40.75	32.93	5.00	228.00
Persistency	520	6.62	0.88	2.76	12.31
Milk yield (kg)	520	3,588.31	1,183.98	1,017.00	8,141.00

breed group and the random effects of cow and residual. Least square means for IY, PY, DTP, PST and MY were estimated for breed groups (BG1 to BG5) and were compared using t-tests. Lactation patterns for breed groups were created using least square means of predicted daily test-day milk yields.

Variance and covariance components were estimated by restricted maximum likelihood procedures (REML) using an average information (AI) algorithm (ASREML; Gilmour *et al.*, 2000). The dataset did not allow the analysis of more than two traits at a time. Thus, ten pairwise sets of computations (IY and PY; IY and DTP; IY and PST; IY and MY; PY and DTP; PY and PST; PY and MY; DTP and PST; DTP and MY; and PST and MY) were carried out using ASREML. These two-trait analyses yielded four estimates of variance and four heritabilities (\pm standard error) for each trait and a single covariance and correlation estimate (\pm standard error). The four heritability estimates and their standard errors were averaged to produce a single estimate of heritability \pm standard error.

The two-trait animal model was as follows:

$$\mathbf{y} = \mathbf{X}\mathbf{b} + \mathbf{Z}_{ga}\mathbf{g}_a + \mathbf{Z}_a\mathbf{a}_a + \mathbf{e} [1]$$

where:

\mathbf{y} = vector of pairs of traits (IY and PY; IY and DTP; IY and PST; IY and MY; PY and DTP; PY and PST; PY and MY; DTP and PST; DTP and MY; and PST and MY),

\mathbf{b} = vector of contemporary groups (herd-

year-season) and calving age (month),

\mathbf{g}_a = vector of breed groups (BG1 = Holstein; H, BG2 = $0.9687 \leq H < 1.00$, BG3 = $0.9375 \leq H < 0.9687$, BG4 = $0.875 \leq H < 0.9375$ and BG5 = $0.50 \leq H < 0.875$),

\mathbf{a}_a = vector of animal random additive genetic effects,

\mathbf{e} = vector of residuals,

\mathbf{X} = matrix of 1's and 0's that relates cow records to elements of vector \mathbf{b} ,

\mathbf{Z}_{ga} = matrix of expected fractions of H alleles relating cow records to elements of vector \mathbf{g}_a , and

\mathbf{Z}_a = matrix 1's and 0's that relates cow records to elements of vector \mathbf{a}_a .

The assumptions of the model were:

$$\begin{bmatrix} \mathbf{y} \\ \mathbf{a}_a \\ \mathbf{e} \end{bmatrix} \sim \text{MVN} \left(\begin{bmatrix} \mathbf{X}\boldsymbol{\beta} \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \mathbf{Z}_a\mathbf{G}_a\mathbf{Z}_a' + \mathbf{R} & \mathbf{Z}_a\mathbf{G}_a & \mathbf{R} \\ \mathbf{G}_a\mathbf{Z}_a' & \mathbf{G}_a & 0 \\ \mathbf{R} & 0 & \mathbf{R} \end{bmatrix} \right)$$

where:

$\mathbf{G}_a = \mathbf{G}_o \otimes \mathbf{A}$, where \mathbf{G}_o is the matrix of additive genetic covariances, \mathbf{A} is the numerator relationship matrix (Henderson, 1976), and \otimes represents direct product (Searle, 1982), and

\mathbf{R} = residual covariance matrix.

The estimated breeding values (EBV; $\hat{\mathbf{u}}_{a_{ij}}$) were computed as the sum of additive genetic group (breed group) effects and random additive genetic effects:

$$\hat{\mathbf{u}}_{a_{ij}} = \bar{\mathbf{g}}_{a_i} + \hat{\mathbf{a}}_{a_{ij}}$$

where $\hat{u}_{a_{ij}}$ is the EBV of animal ij ,

\bar{g}_{a_i} is the estimate of additive genetic group i ,

$\bar{a}_{a_{ij}}$ is the prediction of the random additive genetic effect for animal ij .

Yearly means of EBV and EPV (estimated phenotypic value) for IY, PY, DTP, PST and MY were computed for cows, sires and dams. The EBV and EPV for IY, PY, DTP, PST and MY of individual animals were those from two-trait analyses of IY-MY, PY-MY, DTP-MY, PST-MY and PY-MY respectively. Linear regressions of EBV yearly means on years were computed for each trait using the REG procedure of the SAS software (SAS, 2003). The CORR procedure of SAS (SAS, 2003) was used to compute Pearson correlation coefficients among EBV of cows, sires and dams for all traits.

RESULTS AND DISCUSSION

Least square means

Least square means and standard errors for IY, PY, DTP, PST and MY by breed group of first lactation cows is shown in Table 2. The least square means ranged from 14.16 ± 0.71 kg (BG5; $0.50 \leq H < 0.875$) to 16.04 ± 0.66 kg (BG4; $0.875 \leq H < 0.9375$) for IY, 18.23 ± 0.55 kg (BG5) to 19.84 ± 0.51 kg (BG4) for PY, 36.51 ± 3.78 d (BG4) to 52.04 ± 9.74 d (BG1; purebred H) for DTP, 6.45 ± 0.24 (BG1) to 6.71 ± 0.11 (BG3; $0.9375 \leq H < 0.9687$) for PST, and from 4,083.74

± 103.50 kg (BG5) to $4,317.15 \pm 111.56$ kg (BG3) for MY. Figure 1 presents the lactation patterns for all breed groups. Cows in this population had PY and DTP close to, but PST and MY smaller than cows in Australia and New Zealand (Jamrozik *et al.*, 2002). However, all lactation pattern parameters (IY, PY, DTP and PST) in this Thai dairy multibreed population were smaller than values for dairy populations in Tunisia (Rekik *et al.*, 2003), Japan (Choumei *et al.*, 2006), Canada and Italy (Jamrozik *et al.* 2002).

Breed group differences were non-significant for all traits. However, there was a general trend for crossbred cows to outperform H cows (Table 2). Cows in BG3 had higher MY and PST than any other group, including H (BG1) and 97% H (BG2), whereas the crossbred group BG4 showed the largest least square means for IY, PY and DTP. These results suggested that cows that had $H \geq 0.9687$ (BG1 and BG2) were less able to cope with the management, nutrition and climatic conditions in the central region of Thailand. These differences in MY were similar to other dairy populations in Thailand (Koonawootrittriron *et al.*, 2001) and other countries (e.g., Grossman *et al.*, 1999; Fadlilmoula *et al.*, 2007). The adaptability of these cows was related to environmental conditions and the management provided by farmers in these locations (Markvichitr *et al.*, 1995; Tumwasorn *et al.*, 1995; Punyapornwithaya *et al.*, 2005). Thus, for cows in groups BG1 and BG2 to reach their production potential, changes in management (e.g., active cooling), nutrition (e.g.,

Table 2 Least square means and standard errors for initial yield, peak yield, days to peak, persistency and milk yield by breed group of cows.

BG	Breed group	No.	Initial yield (kg)	Peak yield (kg)	Days to peak (day)	Persistency	Milk yield (kg)
1	Holstein	22	14.60 ± 1.71	18.78 ± 1.32	52.04 ± 9.74	6.45 ± 0.24	$4,170.43 \pm 249.77$
2	$0.9687 \leq H < 1.00$	81	14.99 ± 0.91	18.83 ± 0.71	43.86 ± 5.21	6.69 ± 0.13	$4,195.80 \pm 133.49$
3	$0.9375 \leq H < 0.9687$	118	15.30 ± 0.76	19.42 ± 0.59	40.61 ± 4.36	6.71 ± 0.11	$4,317.15 \pm 111.56$
4	$0.875 \leq H < 0.9375$	160	16.04 ± 0.66	19.84 ± 0.51	36.51 ± 3.78	6.50 ± 0.09	$4,112.28 \pm 97.01$
5	$0.50 \leq H < 0.875$	139	14.16 ± 0.71	18.23 ± 0.55	42.92 ± 4.04	6.66 ± 0.10	$4,083.74 \pm 103.50$

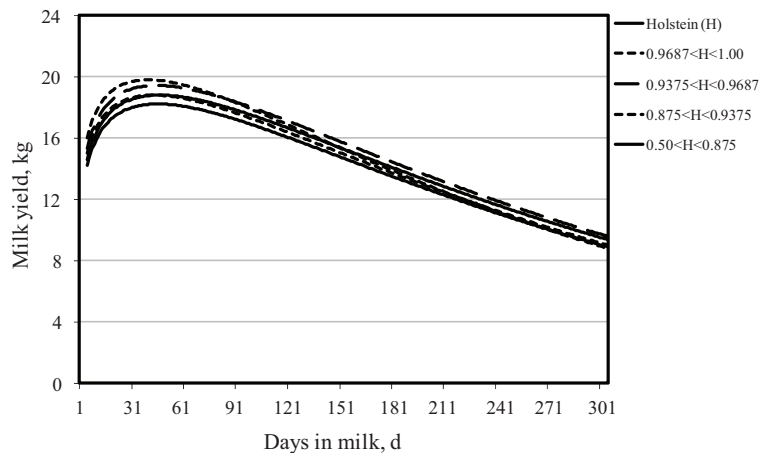


Figure 1 Lactation patterns for Holstein (H), $0.9687 \leq H < 1.00$, $0.9375 \leq H < 0.9687$, $0.875 \leq H < 0.9375$ and $0.50 \leq H < 0.875$.

better quality roughage or concentrate), and health care may be needed. Some of these changes may, however, prove to be unprofitable under Thai economic conditions. Decreasing or maintaining H fraction at or below 90% for replacement cows could be a desirable alternative to keep farms profitable when management and nutrition are limiting factors (Koonawootrittriron *et al.*, 2008).

Genetic parameters

Table 3 shows estimates and standard errors of the heritability of and correlations among IY, PY, DTP, PST and MY. The heritability estimates were 0.23 ± 0.18 for IY, 0.20 ± 0.18 for PY, 0.52 ± 0.28 for DTP, 0.21 ± 0.19 for PST, and 0.43 ± 0.24 for MY. This range of heritability estimates was close to values reported in the

literatures (Ferris *et al.*, 1985; Varona *et al.*, 1998; Rekaya *et al.*, 2000), and it suggested that these traits could be improved by genetic selection. Thus, dairy genetic evaluation for IY, PY, DTP and PST of sires and dams used in this region or in Thailand should be considered in addition to MY. Individual sire EBV for these traits should also be published in sire summaries to allow farmers to use this information for selection purposes.

Genetic correlation estimates between MY and IY, PY, DTP and PST were 0.40 ± 0.45 , 0.62 ± 0.30 , 0.36 ± 0.33 , and 0.56 ± 0.39 , respectively. Phenotypic correlation estimates between MY and IY, PY, DTP and PST were 0.23 ± 0.16 , 0.53 ± 0.04 , 0.22 ± 0.06 and 0.38 ± 0.33 , respectively. These correlation estimates indicated

Table 3 Heritability (h^2 ; diagonal), genetic correlation (r_g ; upper diagonal) and phenotypic correlation (r_p ; lower diagonal) for initial yield, peak yield, days to peak, persistency, and milk yield of cows.

$r_p \backslash r_g$	Initial yield	Peak yield	Day to peak	Persistency	Milk yield
Initial yield	0.23 ± 0.18	0.99 ± 0.01	-0.98 ± 0.20	-0.17 ± 0.60	0.40 ± 0.45
Peak yield	0.80 ± 0.02	0.20 ± 0.18	-0.17 ± 0.60	-0.28 ± 0.06	0.62 ± 0.30
Days to peak	-0.68 ± 0.03	-0.31 ± 0.06	0.52 ± 0.28	0.98 ± 0.18	0.36 ± 0.33
Persistency	-0.54 ± 0.04	-0.31 ± 0.06	0.65 ± 0.04	0.21 ± 0.19	0.56 ± 0.39
Milk yield	0.23 ± 0.06	0.53 ± 0.04	0.22 ± 0.06	0.38 ± 0.33	0.43 ± 0.24

that a higher MY was associated with higher IY, higher PY, longer DTP and higher PST. Higher estimates of phenotypic correlations suggested that changes in PY or PST would affect MY more than changes in IY or DTP. However, the genetic correlation estimate between PST and PY was negative (-0.28 ± 0.06) indicating that selecting for one of these traits (PY or PST) would negatively affect the other trait, which would be undesirable. Thus, multiple-trait genetic selection for improving MY by changing PY or PST should be considered carefully. However, research results elsewhere (Solknér and Fuchs, 1987; Grossman *et al.*, 1999; Muir *et al.*, 2004) have suggested that cows with moderate PY and high PST throughout lactation usually have less stress, better health status, better reproductive efficiency and more efficient use of cheap roughage than cows with low PST and high PY. Cows in this Thai multibreed dairy population had PY and DTP comparable to but had PST and MY smaller than dairy populations in Australia and New Zealand (Jamrozik *et al.*, 2002). Thus, in order to improve MY by changing the shape of the lactation pattern under Thai tropical conditions, increasing PST should be preferred to increasing PY.

Genetic and phenotypic trends

Phenotypic trends constructed using the yearly EPV means of cows were negative for IY (-0.30 ± 0.20 kg/yr; $P > 0.05$) and positive for PY (0.16 ± 0.17 kg/yr; $P > 0.05$), DTP (0.05 ± 0.02 d/yr; $P > 0.05$), PST (2.37 ± 1.41 /yr; $P > 0.05$), and MY (39.64 ± 51.34 kg/yr; $P > 0.05$). Genetic trends from yearly EBV means of cows were positive and close to zero. They were 0.09 ± 0.09 kg/yr for IY ($P > 0.05$), 0.13 ± 0.09 kg/yr for PY ($P > 0.05$), 0.66 ± 0.29 d/yr for DTP ($P > 0.05$), 0.01 ± 0.01 /yr for PST ($P > 0.05$), and 0.55 ± 0.26 kg/yr for MY ($P > 0.05$). Trends for MY in this population had smaller values than those reported by the Department of Livestock Development (2006; EPV 78.57 ± 8.66 kg/yr; and EBV 3.32 ± 0.73 kg/yr),

which used a larger dataset gathered from dairy farms in all parts of Thailand. Cow genetic trends were positively associated with sire genetic trends and negatively associated with dam genetic trends for IY ($r = 0.91$ vs. -0.64), PY ($r = 0.84$ vs. -0.74) and PST ($r = 0.62$ vs. -0.59), with the reverse for DTP ($r = 0.83$ vs. -0.18) and MY ($r = 0.99$ vs. 0.89).

Milk production is the most economically important trait in central and other parts of Thailand. Selection of sires and dams for the next generation is mainly based on high milk yield. Small values of genetic trends found for MY in this population suggested that selection efforts by farmers to increase MY have had limited success, perhaps due to insufficient changes in lactation patterns (IY, PY, DTP or PST). This slow progress may be related to farmers choosing sires and dams based on considerations other than their EBV (e.g., cost, health, reproductive performance and pedigree), low accuracy of sire and dam EBV, limited availability of EBV for imported sires under Thai conditions and genotype by environment interaction as indicated by Koonawootrittriron *et al.* (2008).

Rhone *et al.* (2008a) reported that the majority of farmers in Central Thailand had primary or high school education, the majority of them received dairy production information through training from dairy cooperatives, and that 44 to 52% of the farmers recorded milk production of individual cows on their farms. Furthermore, Rhone *et al.* (2008b) indicated that farms that kept individual animal records and used EBV to select sires achieved higher herd performance than farms that did not. Thus, to improve MY and the lactation pattern of cows (IY, PY, DTP or PST), increasing knowledge and understanding of dairy genetic selection, mating, data recording, and data utilization through training by cooperatives should be considered. Data collection at the farm level should be increased in terms of number and reliability. A national dairy genetic evaluation and

publication of sire EBV should be regularly conducted to provide accurate genetic information on sires being considered for improvement of dairy productivity and genetic trends under Thai environmental conditions.

CONCLUSIONS

Least square means differences among breeding groups for lactation pattern traits and milk yield were non-significant. However, crossbred cows in BG3 had better PST and MY, while those in BG4 had better IY, PY and DTP than purebred H cows, indicating that a high percentage of crossbred H cows would be the dairy cow of choice under the current management, nutritional and health conditions in Central Thailand. Estimates of heritabilities and genetic correlations suggested that selection for PY and PST would help increase MY. However, PY and PST were negatively correlated, thus a multiple-trait selection program will be necessary to increase MY without detrimental effects on PY and PST. Genetic trends were near zero for all traits indicating that the selection procedures for sires and dams need to be improved and closely monitored to increase yearly genetic gains. A national dairy genetic evaluation system needs to be implemented to provide farmers with accurate and timely genetic information for selection of sires and dams.

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