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Genetic and Environmental Factors Affecting Weaning-to-First Service Interval in a Landrace-Large White Swine Population in Northern Thailand

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ABSTRACT

Non-productive sow days measured as weaning-to-first service interval (WSI) is an economically important trait in commercial swine production. A reduction in WSI would increase efficiency and decrease production costs. The aim of this study was to characterize genetic and environmental factors affecting WSI in a Landrace-Large White commercial swine population in Chiang Mai, Northern Thailand. The dataset contained information from 11,737 litters and 2,468 sows collected from 1989 to 2008. Sows were raised in an open-house system and received the same feeding and management. Four breed groups were represented: Landrace (L), Large White (T), L × T (LT), and T × L (TL). Parity of sow was classified as 1, 2, 3, 4, 5, 6, and ≥ 7. Seasons were winter (November to February), summer (March to June), and rainy (July to October). Year-season of farrowing was important source of variation (P < 0.0001). The WSI ranged from 4.38 ± 0.67 d (1991-winter) to 9.68 ± 1.14 d (1989-rainy). Gilts had longer WSI (8.54 ± 0.14 d) than multiparous sows (5.80 ± 0.19 d to 6.33 ± 0.14; P < 0.0001). Landrace had similar WSI (6.10 ± 0.10 d) to T sows (6.00 ± 0.09 d). Crossbred LT sows (6.43 ± 0.20 d) and TL sows (7.04 ± 0.20 d) had longer WSI than purebreds sows (P < 0.0001). Heterosis estimates for WSI were 0.31 ± 0.20 d (P < 0.12) for LT sows and 0.91 ± 0.20 d (P < 0.0001) for TL sows. The WSI heritability estimate was low (0.024 ± 0.010) due primarily to a low estimate of additive genetic variance. Introduction of unrelated animal to the population may increase additive genetic variation and increase potential for genetic improvement for WSI.

Key words: genetic, reproduction, swine, tropical, weaning-to-first-service interval

INTRODUCTION

Improvement of sow efficiency in commercial swine production systems in Thailand has focused primarily on increasing number of piglets born alive. Non-productive sow days, measured as weaning-to-first service interval (WSI), weaning-to-first estrus interval (WEI), or weaning-to-conception interval has been frequently ignored. Non-productive sow days is an economically relevant trait for commercial swine production because longer sow non-productive days increase maintenance costs and decrease sow efficiency.

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A number of factors have been found to be associated with non-productive sow days. Seasonal variations (temperature and humidity) influenced on WSI in crossbred Landrace × Yorkshire sows (Suriyasomboon *et al.*, 2006) and in purebred Landrace and Yorkshire sows (Tantasuparuk *et al.*, 2000a). Sows had longer WSI when weaning occurred in the hot and humid season. Breed groups were found to be a significant source of variation for non-productive sow days in populations of Landrace, Large White, and reciprocal crossbred pigs (WEI; Suwanasopee *et al*., 2005a) and Danish Landrace and Danish Landrace × Native Lithuanian White pigs (WSI; Karvelienè *et al.*, 2008). In both cases, crossbred sows had longer non-productive sow days than purebred sows. Parity of sow affected non-productive sow days differently in gilts and sows (Koketsu and Dial, 1997; Tantasuparuk *et al*., 2001; Suwanasopee *et al.*, 2005a). Gilts tended to have longer non-productive sow days than sows, perhaps because of lower energy reserves. Lactation length prolonged WSI indirectly due to weight losses above 5% in gilts and 10% in sows (Thaker and Bilkei, 2005).

Most non-productive sow days swine research in Thailand has been focused on management, reproductive, and nutritional aspects. Few studies have investigated non-productive sow days from a genetic selection perspective (Suwanasopee *et al.*, 2005b; Imboonta *et al.*, 2007) and none of them were in open-house systems. Any reduction in non-productive sow days under Thai tropical conditions would help increase sow efficiency and lower production costs for commercial swine producers. Thus, the objectives of this study were to characterize genetic and environmental factors affecting WSI and to estimate its heritability and repeatability in a Landrace-Large White commercial swine population raised in an open-house system in Chiang Mai, Northern Thailand.

MATERIALS AND METHODS

Dataset and animals

The dataset contained WSI records from 11,737 litters and 2,468 sows collected from 1989 to 2008 in a commercial swine population in Chiang Mai province, Northern Thailand. Breed groups of sows were purebred Landrace (L) and Large White (T), and reciprocal crossbred groups L × T (LT) and T × L (TL). Parity of sows was classified as 1, 2, 3, 4, 5, 6, and ≥ 7.

Climate, nutrition and management

Average temperature and relative humidity in this region were 26.2°C (ranged from 12 to 38°C) and 71.6% (ranged from 40 to 90%) respectively (Khedari *et al.*, 2002). Seasons were classified as winter (November to February), summer (March to June), and rainy (July to October). Sows were managed in an open-housing system. Cooling systems were foggers for breeders and dippers for farrowing-nursling sows that were activated when the ambient temperature was higher than 33°C. Breeder sows were fed 2.5 kg feed/d (16% crude protein and 3,200 to 3,500 kcal/kg feed) divided into two feeding times (7:00 and 13:00). Farrowing-nursling sows were fed 5 to 6 kg feed/d (17 to 18% crude protein and 4,060 kcal/kg feed) separated into 4 feeding times (7:00, 10:00, 13:00, and 15:00). Piglets were weaned at approximately 26 d after parturition. Number of piglets weaned ranged from 0 to 20 piglets (mean = 8.51 piglets; SD = 2.72 piglets). Estrus of gilts and sows was detected by boar exposure two times a day (7:00 to 8:00 and 15:00 to 16:00 pm), and then they were artificially inseminated twice with diluted semen from the same boar. The first insemination occurred 12 h after estrus was detected, and the second one was 12 h later.

Data analysis

The WSI data were analyzed using the following linear model:

$$y_{ijkl} = \mu + FYS_i + PR_j + BG_k + b_1 LL_{ijkl} + b_2 LL2_{ijkl} + b_3 NPW_{ijkl} + e_{ijkl}$$

where **y** = the phenotypic observation for WSI, **μ** = population mean for WSI, **FYS** = farrowing year-season effects (i = 1 to 56), **PR** = parity of sow (j = 1 to 7), **BG** = breed groups of sow (k = 1 to 4), **LL** = lactation length, **LL2** = square of lactation length, b_1 = linear regression of WSI on lactation length, b_2 = quadratic regression of WSI on lactation length, **NPW** = number of piglets weaned, b_3 = linear regression of WSI on number of piglets weaned, and **e** = random residuals effects. Random residual effects were assumed to have mean equal to zero, common variance, and uncorrelated. Computations were carried out using the MIXED procedure of SAS (SAS, 2003). Least squares means for BG and PR were compared using a Bonferroni t-test. The WSI difference between crossbred and purebred sows was computed using the estimate command within the MIXED procedure of SAS, and tested for significance with a t-test. In addition, heterosis differences (HD) for WSI were estimated for each reciprocal crossbred group by subtracting their least squares means (LT or TL) from the average of the least squares means of the parental breeds (0.5 * (L + T)). Heterosis percentage (HP) was computed as 100 times the ratio of HD to the parental average (HD*100)/(0.5*(L+T)).

Variance components for WSI were estimated using restricted maximum likelihood procedures using an average information algorithm (ASREML; Gilmour *et al.*, 2000). The mixed model used to estimate genetic and environmental variance components utilized the same set of effects found to be important in the fixed model for WSI, plus additive genetic effect of the sow, permanent environmental effect of the sow, and a residual effect. Additive genetic sow effects were assumed to have mean equal to their genetic group (i.e., L, T, LT, and TL) and variance equal to $A*\sigma_A^2$, where A = additive relationship matrix among animals in the pedigree file, and σ_A^2 = additive genetic variance for WSI. Permanent environmental effects were assumed to have mean zero and variance equal to $I*\sigma_{Ep}^2$, where I = identity matrix, and σ_{Ep}^2 = permanent environmental variance. Residual effects were assumed to have mean zero and variance equal to $I*\sigma_R^2$, where σ_R^2 = residual variance.

RESULTS AND DISCUSSION

Means, standard deviations (SD), minimum, and maximum values for WSI by breed group of sow and total are shown in Table 1. The dataset had a larger proportion of purebred sows (54.34 % L and 32.21 % T) than crossbred sows (6.60 % LT and 6.85 % TL). The overall mean for WSI in this Landrace-Large White swine population was 6.47 d, the SD was 5.88 d, the minimum value was 0 d, and the maximum value was 89 d. The mean WSI by breed group ranged from 6.18 d for T to 6.97 d for TL, whereas the SD ranged from 5.49 d for T to 7.07 d for TL. Large White had the shortest range (0 to 53 d), TL

Table 1 Descriptive statistics for weaning-to-first service interval by breed group and total.

Breed group	Number sows	%	Number records	Mean (d)	Standard deviation (d)	Min (d)	Max (d)
Landrace (L)	1,341	54.34	5,729	6.61	5.99	0	85
Large White (T)	795	32.21	4,126	6.18	5.49	0	53
L × T	163	6.60	935	6.35	5.52	0	87
T × L	169	6.85	947	6.97	7.07	0	89
Total	2,468	100.00	11,737	6.47	5.88	0	89

had the longest range (0 to 89 d), and L and LT had ranges similar to TL. Means for L and T breeds in this Northern Thai herd were smaller (6.61 d for L and 6.18 d for T) than those reported in Central Thailand (7.9 d for Landrace and 8.2 d for Yorkshire) by Tantasuparuk *et al.* (2001). On the other hand, the mean and standard deviation for the combined LT and TL crossbred groups (mean = 6.66 d; SD = 6.36 d) was higher than that obtained for Landrace × Yorkshire crossbred sows in Central Thailand (mean = 5.9 d; SD = 4.6 d; Suriyasomboon *et al.*, 2006).

The largest fraction of sows in the dataset was gilts (20.59 %), followed by decreasing percentages for second and later parities (Table 2). Means and SD for WSI by parity were larger for the first parity (mean = 8.49 d; SD = 8.59 d) than for subsequent parities (mean ranged from 5.70 d to 6.13 d, and SD ranged from 4.34 d to 4.93 d). The WSI range was longer in first parity (87 d) than in later parity sows, and it tended to decrease over time, except those 7 yr or older. Similarly, first parity sows in a larger Landrace population had larger mean (8.03 d) and SD (7.98 d) than second (mean = 5.72 d; SD = 4.25 d) and third (mean = 5.47 d; SD = 4.12 d) parities under Thai tropical conditions (Imboonta *et al.*, 2007).

Farrowing year-season

Least squares means for WSI fluctuated substantially across farrowing year-seasons (Figure 1). The shortest WSI occurred in winter of 1991 (4.38 ± 0.67 d; $P < 0.0001$) and the longest WSI was in the winter season of 1990 (10.08 ± 1.01 d; $P < 0.0001$). Least squares means within seasons across years ranged from 4.38 ± 0.67 d ($P < 0.0001$) in 1991 to 10.08 ± 1.01 d ($P < 0.0001$) in 1990 for winter, from 4.50 ± 0.67 d ($P < 0.0001$) in 1991 to 8.16 ± 0.46 d ($P < 0.0001$) in 1996 for summer, and from 4.62 ± 0.62 d ($P < 0.0001$) in 1991 to 9.68 ± 1.14 d ($P < 0.0001$) for the rainy season. Although least squares means for WSI within seasons tended to increase from 1989 to 2008, none of the coefficients of regression of WSI on years within seasons was significant (winter: 0.04 ± 0.06 d; $P < 0.44$; summer: 0.07 ± 0.04 d; $P < 0.15$; rainy: 0.02 ± 0.05 d; $P < 0.65$). Differences between coefficients of regression of WSI on years within seasons were also non-significant. Thus, season was not a major source of variation for WSI in this swine population. This means that sows that farrowed piglets in winter, summer, and rainy seasons had similar WSI values. Thus, it appears that differences in temperature and humidity in the Chiang Mai area during the years of the study were not severe enough to have a significant effect on WSI. This appears not to have been the case in a Landrace and Yorkshire swine population in Central Thailand (Tantasuparuk *et al.*, 2000a), where WSI was reported to have been longer from April to August (part of summer and rainy seasons) than during the rest of the year. Similarly, Suriyasomboon *et al.* (2006) found that Landrace × Yorkshire crossbred sows that weaned piglets in May to August (late summer and early rainy seasons) tended to have longer WSI than sows that weaned piglets between September and April.

Table 2 Descriptive statistics for weaning-to-first service interval by parity of sow.

Parity	Number records	%	Mean (d)	Standard deviation (d)	Min (d)	Max (d)
1	2,417	20.59	8.49	8.59	0	87
2	2,037	17.36	6.13	4.87	0	85
3	1,750	14.91	6.02	4.93	0	62
4	1,488	12.68	5.76	4.23	0	54
5	1,283	10.93	5.99	4.69	0	50
6	1,047	8.92	5.70	4.34	0	53
≥ 7	1,715	14.61	5.90	5.42	0	89

Parity

Least squares means of WSI by parity are shown in Figure 2. First-parity sows had longer WSI (8.54 ± 0.14 d) than second and later parity sows (range from 5.80 ± 0.19 d to 6.33 ± 0.14; P < 0.0001). Second and later parity sows had similar WSI least squares means. Accordingly, sows in this population were separated into two distinct groups, primiparous sows with longer WSI and multiparous sows with shorter WSI. This has been reported by several investigators (Koketsu and Dial, 1997; Tantasuparuk *et al*., 2001; Imboonta *et al*., 2007). Longer WSI in primiparous sows may have been related to difficulties in balancing

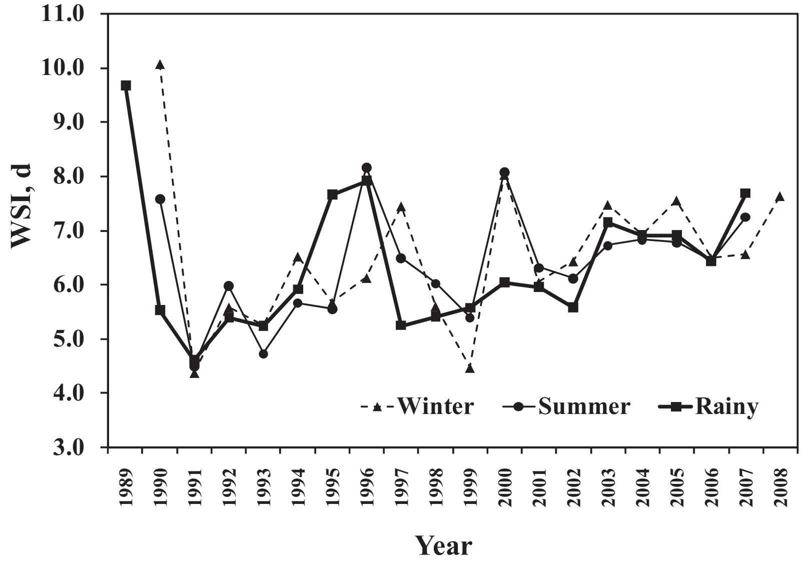

Figure 1 Least squares means for weaning-to-first service interval (WSI) by season across years from 1989 to 2008.

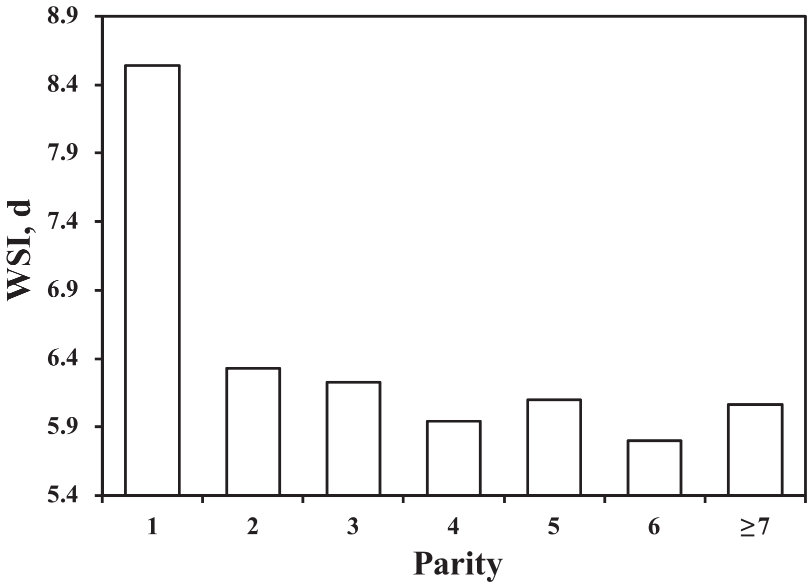

Figure 2 Least squares means for weaning-to-first service interval (WSI) by parity of sow.

their higher energy and protein requirements for growth and production of milk for nursling their piglets than those of multiparous sows (Reese *et al*., 1982; Einarsson *et al*., 1998). These higher nutritional demands for growth in addition to nutritional demands to produce milk for their first litter may have strained their ability to return estrus as quickly as multiparous sows after weaning. Follicles in lactating gilts may have taken longer to mature because of their metabolic requirements took longer to be met than in older sows (Quesnel *et al*., 2007). Multiparous sows, being more mature than primiparous sows, may have had more energy reserves to generate mature follicles and to return to estrus sooner than gilts after weaning.

Body weight losses during lactation may have also contributed to longer WSI for primiparous sows here. Thaker and Bilkei (2005) found that WSI increased ($P < 0.05$) when gilts lost more than 5% of their body weight, whereas a 10% body weight loss was required for second and later parity sows. Lastly, estrous detection may have played a role if gilts showed less evident signs of estrous than multiparous sows. Missed estruses in gilts may have affected service date, potentially making their WSI longer.

Breed groups and heterosis

Breed group and heterosis least squares means for WSI are shown in Figure 3. Purebred L sows had similar WSI (6.10 ± 0.10 d) to T sows (6.14 ± 0.10 d) in the open-house system of this swine herd in Northern Thailand. Tantasuparuk *et al*. (2001) also found WSI to be similar in purebred Landrace (8.2 d) and Yorkshire (7.9 d) under an open-house system in Central Thailand. On the other hand, Suwanasopee (2006) found longer ($P < 0.05$) WEI in purebred Landrace (5.53 ± 0.07 d) than Large White (4.19 ± 0.07 d) under a closed-house system temperature and humidity control in Thailand.

Crossbred LT sows (6.43 ± 0.20 d) and TL sows (7.04 ± 0.20 d) had longer WSI than purebreds sows (1.22 ± 0.30 d; $P < 0.0001$), and LT crossbreds had shorter WSI than their reciprocal TL crossbreds ($P < 0.02$). The only previous comparison between crossbred and purebred sows for non-productive sow days in

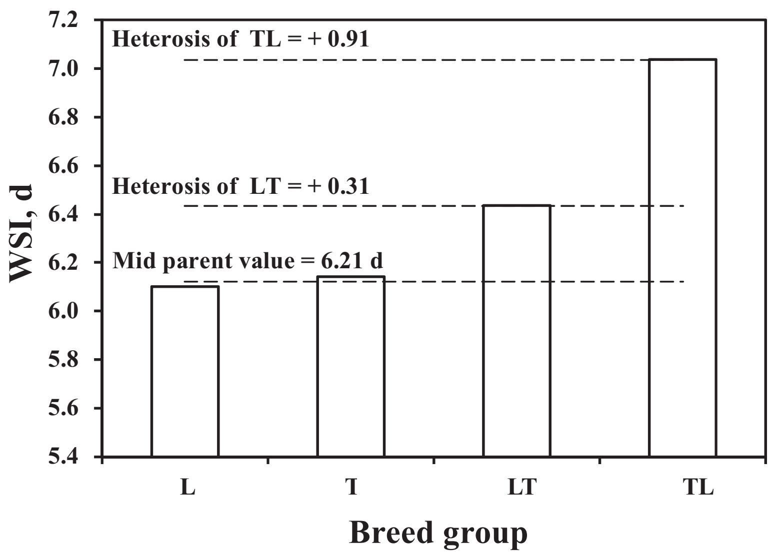

Figure 3 Breed group and heterosis least squares means for weaning-to-first service interval (WSI); L = Landrace, T = Large White, LT = Landrace × Large White, and TL = Large White × Landrace.

Thailand (Suwanasopee, 2006) reported that crossbred Landrace × Large White (5.69 ± 0.07 d) and Large White × Landrace (5.63 ± 0.07 d) had longer WEI than for purebred sows ($P < 0.05$). However, contrary to results here, WEI least squares means for the two reciprocal crossbred groups were similar. Genetic characteristics of the purebred and crossbred animals in the two swine populations as well as differences environmental conditions (e.g., differences in temperature and humidity) may have contributed to LT and TL being different in the open-house system in Northern Thailand, but not in the closed-house system in Central Thailand.

Heterosis estimates for WSI were 0.31 ± 0.20 d ($P < 0.12$) for LT sows, 0.91 ± 0.20 d ($P < 0.0001$) for TL sows, and 0.61 ± 0.15 d ($P < 0.0001$) for the combined LT and TL crossbred groups. Heterosis estimates for WSI in Thailand were unavailable. However, Suwanasopee *et al.* (2007) reported WEI heterosis values for Landrace × Large White (0.36 ± 0.04 d), Large White × Landrace (0.26 ± 0.05 d), and the combined reciprocal crossbred groups (0.32 ± 0.04 d) that were comparable to the LT heterosis estimate for WSI here.

Longer WSI in crossbred than in purebred sows (1.22 ± 0.30 d; $P < 0.0001$) may be an indication that crossbreds were less adapted than purebreds under Northern Thailand tropical conditions. However, crossbred sows had larger (0.34 ± 0.13 piglets; $P < 0.0092$) and heavier (2.8 ± 0.92 kg/litter; $P < 0.0025$) litters than purebred sows. Crossbred sows may have dedicated a larger fraction of nutrients to produce the higher level of milk production required to feed larger litters of piglets than purebred sows. This reallocation of nutrients in crossbred sows may have lowered their energy reserves to such a degree that a longer period was required to produce mature follicles and return to estrous after weaning their litters. Purebred and crossbred were under the same nutritional regime. Perhaps a higher level of nutrition for crossbred sows would have decreased WSI to lengths comparable to those of purebred sows.

Lactation length

There was a quadratic association between WSI and lactation length. The estimate of the linear regression coefficient was negative (-0.80 ± 0.17 d WSI/d LL; $P < 0.0001$) and the estimate of the quadratic regression coefficient was positive (0.014 ± 0.003 d WSI/d^2 LL; $P < 0.0001$). Contrarily, LL had no significant effect on WSI in a Landrace and Yorkshire swine population in Central Thailand (Tantasuparuk *et al.*, 2000b). Similarly, LL was not an important effect for WEI in a population of Landrace, Large White, and reciprocal crossbred groups in Central Thailand (Suwanasopee *et al.*, 2005a). However, swine studies in temperate countries have found LL to significantly affect WSI (Karvelienè *et al.*, 2008) and WEI (Koketsu and Dial, 1997; Belstra *et al.*, 2004).

The estimated regression coefficients in this swine herd produced a concave line when predicted WSI were plotted against LL. Figure 4 shows the relationship between predicted WSI values computed using the intercept from the fixed effect model plus linear and quadratic regression coefficients for LL ranging from 0 to 40 d. The lowest values of WSI occurred between 26 d and 32 d (vertical lines in Figure 4; predicted WSI values from 7.9 to 8.0 d). This concave relationship between WSI and LL was similar to one found in a large study in the United States (13 commercial herds, 178,519 litters from crossbred and purebred sows; Mabry *et al.*, 1996). However, in the US study the smallest WSI values occurred somewhat earlier in the lactation (between 22 and 27 d). The management system in this Thai herd required sows to have a maximum LL of 35 d. Results here suggest that this 35 d maximum could be decreased to 32 d to help reduce WSI values and sow production costs.

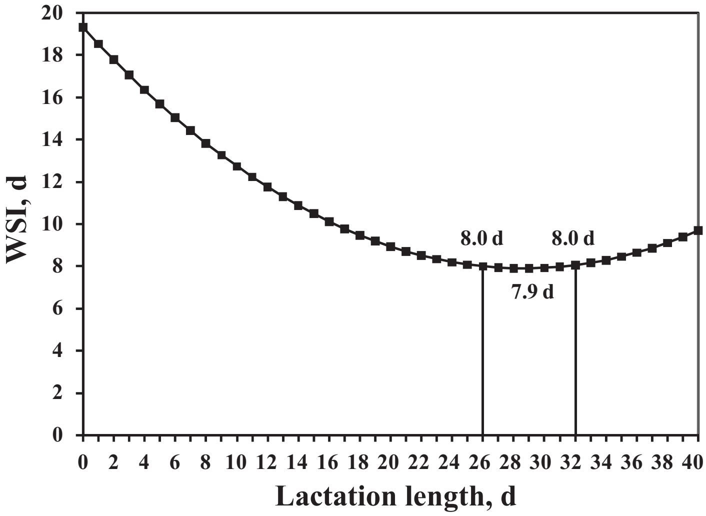

Figure 4 Relationship between predicted weaning-to-first service interval (WSI) and lactation length (LL) between 1 and 40 d. Predicted WSI = Intercept + linear regression coefficient times LL + quadratic regression coefficient times LL squared. Vertical lines indicate the LL (26 d to 32 d) corresponding to the lowest WSI values (7.9 d to 8.0 d).

Variance components and genetic parameters

Restricted maximum likelihood estimates of variance components were 0.80 ± 0.32 d^2 for additive genetic, 1.83 ± 0.39 d^2 for permanent environment, 30.63 ± 0.45 d^2 for environmental, and 33.26 ± 0.45 d^2 for phenotypic (Table 3). The extremely low additive genetic variance estimate for WSI yielded a very low heritability ratio (0.024 ± 0.010), primarily due to the substantially higher estimate for environmental variance. Similarly, the estimate of repeatability was also low (0.079 ± 0.009) because of the proportionally low value of the sum of additive genetic plus permanent environmental variances relative to the phenotypic variance. The low estimate of additive genetic variance may be an indication that the number of Landrace and Large White boars and sows used to generate this population was small, and that perhaps many of the these original animals were related. The large estimate of the environmental variance suggests that this trait is heavily influenced by environmental conditions (management, nutrition, temperature, humidity). Because animals are maintained in an open-house

Table 3 Estimates (± SE) of variance components, heritability, and repeatability for weaning-to-first service interval.

Variance component	
Additive genetic variance	0.80 ± 0.32
Permanent environmental variance	1.83 ± 0.39
Environmental variance	30.63 ± 0.45
Phenotypic variance	33.26 ± 0.45
Genetic parameter	
Heritability	0.024 ± 0.010
Repeatability	0.079 ± 0.009

system, changes in management and nutrition would likely have a larger positive impact than improvements to the ventilation system.

Low heritability and repeatability estimates here were in agreement with estimates of heritability (0.03) and repeatability (0.06) for WEI obtained in a similar Landrace-Yorkshire multibreed population in Central Thailand that also resulted from low estimates of additive genetic (1.17 d^2), permanent environmental (1.16 d^2), and much higher environmental (34.37 d^2) and phenotypic (36.70 d^2) variances (Suwanasopee *et al.*, 2005b). On the other hand, Imboonta *et al.* (2007), using a logarithmic transformation suggested by ten Napel *et al.* (1995) on WSI data from purebred Landrace in Eastern Thailand obtained higher estimates of heritability for WSI in parities 1 to 3 (0.16 ± 0.03 to 0.18 ± 0.04). Similar values of heritability for WSI were estimated in a population of purebred Yorkshire sows in the United States (0.20; Ehlers *et al.*, 2005). This higher heritability in this population relative to the swine population here resulted from a higher additive genetic variance (4.78 d^2 in the Yorkshire population versus 0.80 ± 0.32 d^2 here) and a lower phenotypic variance in the Yorkshire population (23.3 d^2) compared to the phenotypic variance here (33.26 ± 0.45 d^2).

The low additive genetic variance for WSI in this Landrace-Large White multibreed population will severely limit the potential response to selection for this trait. To increase the level of additive genetic variation, importation of unrelated Landrace and Large White animals (primarily boars) of good quality (i.e., low genetic predicted WSI values) from populations within and outside Thailand may be required. In addition, this herd will benefit from a genetic evaluation program for production and reproduction traits of economic importance that include WSI. On the other hand, management and nutritional regimens need to be evaluated, and appropriate changes implemented, particularly in connection with nutritional levels of lactating sows according to their number of piglets. Increasing nutritional levels during lactation for the most prolific sows would help shorten WSI in this swine population.

CONCLUSIONS

Year-season, parity, breed group, and lactation length were all important factors affecting WSI in this population. Non-significant differences between regressions of WSI on year within season proved that WSI was similar in the summer, winter, and rainy seasons. First-parity sows had longer WSI than multiparous sows likely due to higher nutritional requirements for growth and lactation. Purebred L and T sows had similar and lower WSI than LT and TL crossbred sows. The TL sows had the longest WSI of all breed groups, perhaps indicating unmet nutritional demands during lactation. The WSI showed a quadratic relationship with lactation length where the lowest WSI values occurred with lactation lengths from 24 to 32 d, thus perhaps the maximum LL allowed in this population could be lowered from 35 to 32 d. Additive genetic variance and heritability values were very low, suggesting that an increase in genetic variation in this population may be needed to increase potential genetic gains by selection for WSI. Unrelated purebred L and T animals could be brought into the herd to increase additive genetic variation and improve the expected favorable genetic change for WSI in this population.

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