# Effect of service sire on litter size traits in Czech Large White and Landrace pigs

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**ABSTRACT**: The proportion of variance for service sire effect was estimated for three litter size traits (numbers of piglets born, born alive, and weaned) in Czech Large White (89 231 litters) and Czech Landrace (28 320 litters) pigs. Each trait in the first parity was considered as one trait and that trait in the second and subsequent parities was treated as a repeated trait. Consequently, three two-trait animal models were evaluated for each litter size trait: (i) the service sire effect was included and the complete relationship matrix for all the animals (service sires and sows) was taken into account; (ii) the service sire effect was included as a random effect without inclusion of the relationship matrix; (iii) the service sire effect was omitted from the model. Using the residual variance as a criterion, both models including the service sire effect were slightly better than the model without this effect. Estimates of genetic parameters were very similar for the two models including the service sire effect. The proportion of variance for service sire was in the range from 2 to 3% (standard error approx. 0.2%) in Czech Large White and 2% (standard error approx. 0.3%) in Czech Landrace for all three litter size traits and all models. Models without service sire effect or models including service sire as a simple random effect and without inclusion of the genetic relationship matrix are recommended for genetic evaluation of litter size traits.

**Keywords**: pig; litter size traits; genetic parameters; service sire

Litter size traits generally are lowly heritable (Hanenberg et al., 2001; Wolf et al., 2002; Chen et al., 2003). Therefore, using additional information in genetic evaluations may be beneficial for increasing the precision of predicted breeding values. A potential source of information is the effect of service sire. According to van der Lende et al. (1999), service sire can influence both fertilization rate and prenatal survival rate. Such an effect could be due to genetically determined differences in fertilizing capacity (sperm quality) and the genetic contribution of the sire to the viability of the embryo. Although the proportion of variance for litter size traits in pigs attributable to service sire has ranged from 0.00 to 0.05 (Chen et al., 2003; Hamann et al., 2004; Köck et al., 2009), most authors recommend inclusion of the service sire effect in the animal models for genetic evaluation.

Until recently, the service sire effect has not been included in the model equations for genetic evaluation of number of piglets born alive in Czech dam breeds (Wolf et al., 2005), and no information on this effect has been available for those breeds. Therefore, the objective of the present study was to quantify the service sire effect in terms of (co) variance components and to propose models for the potential inclusion of this effect in the linear equations for breeding value estimation. Two additional litter size traits (number of piglets born and number of piglets weaned) were also included in the investigation, because very little information is available on the service sire effect on these traits.

## MATERIAL AND METHODS

### Data

Litter size data were available from Czech Large White and Czech Landrace sows farrowing be-

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tween 1995 and 2008. The litter size traits number of piglets born, number of piglets born alive and number of piglets weaned were analyzed.

For data to be retained for analysis, the following conditions had to be met: litters were purebred Czech Large White or Landrace and had complete information for all litter size traits. Gestation length was in the interval from 105 to 125 days. The minimum sow age at first farrowing was 300 days. Parities greater than 12 were not considered. The age of the sow for parities 1 to 12 had to be in the following intervals (in days): 300 to 500, 450 to 750, 600 to 950, 750 to 1150, 900 to 1350, 1050 to 1550, 1200 to 1750, 1350 to 1950, 1500 to 2150, 1650 to 2350, 1800 to 2550, and 1950 to 2750. The total number of piglets born was between 4 and 22. The number of piglets that died from 24 h after birth until weaning and the number of stillborn piglets was not greater than the mean plus three standard deviations of the corresponding trait. The farrowing interval was between 130 and 300 days. The service sire was known.

There were large differences in herd size. In Czech Landrace, data were available from 54 herds, the number of observations (litters) being in the range from 1 to 2764 with a median of 274. Nine herds (84 observations) with the smallest numbers of observations were excluded. In Czech Large White, data were available from 122 herds, the number of observations (litters) being in the range from 2 to 5695 with a median of 599. In this breed, 21 herds (252 observations) with the smallest numbers of observations were excluded.

For the rest of the herds, a flexible allocation of records to herd-year-season classes was applied. Herd-year-season classes preferably were formed according to natural seasons (spring, summer, autumn, winter) and normally had a length of three months: March through May, June through August, September through November and December through February of the following year. The minimum total number of records for each herd-year-season class was 20 (i.e. if the number of observations in a three-month-

Table 1. Summary statistics for litter size traits for Czech Large White and Landrace breeds

| Variable | Large White | Landrace |
|---|---|---|
| **Numbers** | | |
| Number of sows | 27 717 | 9 891 |
| Number of sires/dams of sows | 1 962/12 721 | 965/4 544 |
| Number of service sires | 2 447 | 1 280 |
| Number of sires/dams of service sires | 847/1 588 | 409/781 |
| Total number of litters | 89 231 | 28 320 |
| Number of the first litters | 25 107 | 8 829 |
| Number of second and subsequent litters | 64 124 | 19 491 |
| Average number of litters per sow | 3.22 | 2.86 |
| Average number of litters per service sire | 36.47 | 22.13 |
| Number of herds | 101 | 45 |
| Number of contemporary groups | 2 599 | 952 |
| **Means (standard deviation)** | | |
| Number of piglets born in the first litter | 11.2 (2.47) | 11.5 (2.58) |
| Number of piglets born in later litters | 12.3 (2.73) | 12.6 (2.86) |
| Number of piglets born alive in the first litter | 10.6 (2.30) | 10.8 (2.39) |
| Number of piglets born alive in later litters | 11.5 (2.48) | 11.7 (2.59) |
| Number of piglets weaned in the first litter | 9.7 (1.96) | 9.8 (1.95) |
| Number of piglets weaned in later litters | 10.2 (2.47) | 10.4 (2.03) |
| Age at the first litter (days) | 374 (38.2) | 368 (36.1) |
| Farrowing interval (days) | 164 (24.8) | 167 (25.6) |

interval was less than 20, the time interval was extended until that number was reached). Because it could happen that no records were available in certain time intervals in a herd, it was ensured that the minimum time interval between the first and the last record in a herd-year-season class was at least 30 days. Assume, e.g., that there were no observations during March and April and the first half of May. Then, independent of the number of observations in the second half of May, that season did not end before mid June. After applying all restrictions and forming herd-year-season classes, 91% of Large White sows and 88% of Landrace sows remained in the final data sets, with 85% and 80% of the original litter size records, respectively.

Summary statistics for the data sets of both breeds are given in Table 1. The data set for Large White was about three times as large as the data set for Landrace.

In both breeds there was about 70% artificial insemination (AI) the proportion of which has been increasing over years. Two subsets of data were formed from the full data sets described above by considering only AI-litters. The number of observations (litters) was 61 740 from 22 830 sows and 1290 boars for Large White and 19 986 from 8128 sows and 883 boars for Landrace.

## Statistical analyses

All calculations were carried out separately for each breed. Each trait in the first parity was considered as one trait and that trait in the second and subsequent parities was treated as a repeated trait. Two-trait models were then calculated according to the following equation:

$$\begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & 0 \\ 0 & \mathbf{X}_2 \end{bmatrix}\begin{bmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{H}_1 & 0 \\ 0 & \mathbf{H}_2 \end{bmatrix}\begin{bmatrix} \mathbf{h}_1 \\ \mathbf{h}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{a_1} & 0 \\ 0 & \mathbf{Z}_{a_2} \end{bmatrix}\begin{bmatrix} \mathbf{a}_1 \\ \mathbf{a}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{s_1} & 0 \\ 0 & \mathbf{Z}_{s_2} \end{bmatrix}\begin{bmatrix} \mathbf{s}_1 \\ \mathbf{s}_2 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & \mathbf{W}_{a_2} \end{bmatrix}\begin{bmatrix} 0 \\ \mathbf{p}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{e}_1 \\ \mathbf{e}_2 \end{bmatrix} \qquad (1)$$

where:

$\mathbf{y}_1, \mathbf{y}_2$ = vectors of observations for the litter size trait under consideration measured in the first or second and subsequent litters, respectively

$\mathbf{b}_1, \mathbf{b}_2$ = vectors of fixed effects

$\mathbf{h}_1, \mathbf{h}_2$ = vectors of random herd-year-season effects

$\mathbf{a}_1, \mathbf{a}_2$ = vectors of additive genetic effects of the sow

$\mathbf{s}_1, \mathbf{s}_2$ = vectors of additive genetic effects of the service sire

$\mathbf{p}_2$ = vector of permanent environmental effects of the sow

$\mathbf{e}_1, \mathbf{e}_2$ = vectors of residual effects

$\mathbf{X}_1, \mathbf{X}_2, \mathbf{H}_1, \mathbf{H}_2, \mathbf{Z}_{a_1}, \mathbf{Z}_{a_2}, \mathbf{Z}_{s_1}, \mathbf{Z}_{s_2}, \mathbf{W}_{a_2}$ = corresponding incidence matrices

index 1 = first litter

index 2 = second and subsequent litters

Both vectors of fixed effects contain the effect of the mating type (natural service or artificial insemination). Quadratic regression on age at first farrowing is a further component of $\mathbf{b}_1$, whereas the effect of the parity number and quadratic regression on the farrowing interval are parts of $\mathbf{b}_2$. The effect of the mating type is omitted in the models for the subsets of data with AI-litters only.

The covariance matrices for the permanent environmental effect of the sow and the residual effect were assumed to be diagonal whereas covariances between traits were allowed for in the herd-year-season effect. A joint covariance matrix for the additive genetic effects and the service sire effects was assumed as done by Kim et al. (2002):

$$\mathbf{var}\begin{bmatrix} \mathbf{a}_1 \\ \mathbf{a}_2 \\ \mathbf{s}_1 \\ \mathbf{s}_1 \end{bmatrix} = \mathbf{A}\otimes\begin{bmatrix} \sigma^2_{a_1} & \sigma_{a_1a_1} & \sigma_{a_1s_1} & \sigma_{a_1s_2} \\ \sigma_{a_1a_2} & \sigma^2_{a_2} & \sigma_{a_2s_1} & \sigma_{a_2s_2} \\ \sigma_{a_1s_1} & \sigma_{a_2s_1} & \sigma^2_{s_1} & \sigma_{s_1s_2} \\ \sigma_{a_1s_1} & \sigma_{a_2s_2} & \sigma_{s_1s_2} & \sigma^2_{s_2} \end{bmatrix} \qquad (2)$$

where:

$\mathbf{a}_1, \mathbf{a}_2$ = vectors of additive genetic effects of the sow

$\mathbf{s}_1, \mathbf{s}_2$ = vectors of additive genetic effects of the service sire

$\sigma^2_{a_1}, \sigma^2_{a_2}$ = additive genetic variance components for the sow

$\sigma^2_{s_1}, \sigma^2_{s_2}$ = variance components for the service sire

σ with 4 indexes = appropriate covariances

index 1 = refers to appropriate litter size traits in the first litter

index 2 = refers to appropriate litter size traits in the second and subsequent litters

$\mathbf{A}$ = relationship matrix

Equations (1) and (2) describe the two-trait model where all genetic relationships among service sires were taken into account.

Two modifications of this two-trait model were calculated. In the first modification, the relationship matrix for the service sires was omitted. In the second modification, the effect of the service sire was completely omitted. All calculations were carried out with the complete data sets and with the subsets composed of AI-litters only.

Pedigrees were traced back roughly to the year 1985. Variances and covariances were estimated using restricted maximum likelihood (REML) and optimization by a quasi Newton algorithm with analytical gradients (Neumaier and Groeneveld, 1998) as implemented in VCE 6.0 program (Groeneveld et al., 2008).

The same models used for (co)variance estimation were used for the prediction of breeding values. For this purpose the PEST program (Groeneveld et al., 1990) was used with the SMP solver yielding the prediction error variances of the predicted breeding values. The mean of the standard errors of prediction over all animals born in the most recent years (2005 to 2008) was used for comparing models.

## RESULTS

First, results for the complete data sets will be presented in detail. Results for the three litter size traits are presented in Tables 2–4 for Czech Large White and Tables 5–7 for Czech Landrace. Using the residual variance as a criterion for the comparison of models, the two models including service sire (with or without inclusion of the relationship matrix) were slightly better than the model without service sire. There were virtually no differences in residual variances between the models including the full genetic relationships among service sires and the models using the service sire effect without inclusion of the relationship matrix. Therefore both models should be of similar efficiency in the genetic evaluation.

The proportion of variance for the service sire effect ranged from 2 to 3% in Czech Large White and equalled approximately 2% in Czech Landrace for all three litter size traits. In Large White, the lower value (2%) was observed for the number of piglets weaned. Similar values for the proportion of variance for the service sire effect were obtained, no matter whether the effect of service sire was estimated with or without inclusion of the relationship matrix. Omitting the effect of the service sire in the model did not influence the heritability estimates. Also the proportion of variance caused by permanent environmental effects of the sow was equal or very similar for all three types of the models.

The proportion of variance for the herd-year-season effect was the lowest for the number of piglets born and the highest for the number of piglets weaned. This tendency was more apparent in the Landrace breed than in Large White.

Table 2. Estimates of genetic parameters (± standard error) for the number of piglets born in the Czech Large White breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 4.31 ± 0.053 | 4.31 ± 0.054 | 4.38 ± 0.056 |
| Heritability | 0.19 ± 0.010 | 0.18 ± 0.010 | 0.19 ± 0.010 |
| Proportion of variance for SS | 0.03 ± 0.003 | 0.03 ± 0.003 | – |
| Proportion of variance for HYS | 0.04 ± 0.004 | 0.04 ± 0.003 | 0.05 ± 0.004 |
| Proportion of residual variance | 0.76 ± 0.010 | 0.75 ± 0.010 | 0.76 ± 0.010 |
| Correlation | –0.09 ± 0.287 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 5.28 ± 0.033 | 5.27 ± 0.032 | 5.38 ± 0.033 |
| Heritability | 0.17 ± 0.006 | 0.16 ± 0.006 | 0.16 ± 0.006 |
| Proportion of variance for SS | 0.03 ± 0.002 | 0.03 ± 0.002 | – |
| Proportion of variance for PE | 0.05 ± 0.005 | 0.05 ± 0.005 | 0.05 ± 0.005 |
| Proportion of variance for HYS | 0.03 ± 0.002 | 0.03 ± 0.002 | 0.03 ± 0.002 |
| Proportion of residual variance | 0.76 ± 0.005 | 0.74 ± 0.005 | 0.76 ± 0.006 |
| Correlation | –0.24 ± 0.222 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Table 3. Estimates of genetic parameters (± standard error) for the number of piglets born alive in the Czech Large White breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 3.70 ± 0.043 | 3.69 ± 0.046 | 3.75 ± 0.049 |
| Heritability | 0.17 ± 0.010 | 0.17 ± 0.010 | 0.18 ± 0.010 |
| Proportion of variance for SS | 0.03 ± 0.003 | 0.03 ± 0.003 | – |
| Proportion of variance for HYS | 0.05 ± 0.004 | 0.05 ± 0.003 | 0.06 ± 0.004 |
| Proportion of residual variance | 0.76 ± 0.004 | 0.75 ± 0.009 | 0.76 ± 0.010 |
| Correlation | –0.08 ± 0.316 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 4.34 ± 0.028 | 4.33 ± 0.028 | 4.41 ± 0.027 |
| Heritability | 0.16 ± 0.006 | 0.16 ± 0.006 | 0.16 ± 0.006 |
| Proportion of variance for SS | 0.03 ± 0.002 | 0.03 ± 0.002 | – |
| Proportion of variance for PE | 0.04 ± 0.005 | 0.04 ± 0.004 | 0.04 ± 0.005 |
| Proportion of variance for HYS | 0.03 ± 0.002 | 0.03 ± 0.002 | 0.04 ± 0.002 |
| Proportion of residual variance | 0.77 ± 0.005 | 0.75 ± 0.005 | 0.76 ± 0.006 |
| Correlation | –0.30 ± 0.243 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Table 4. Estimates of genetic parameters (± standard error) for the number of piglets weaned in the Czech Large White breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 2.74 ± 0.033 | 2.74 ± 0.033 | 2.78 ± 0.033 |
| Heritability | 0.16 ± 0.010 | 0.15 ± 0.009 | 0.15 ± 0.009 |
| Proportion of variance for SS | 0.03 ± 0.004 | 0.03 ± 0.002 | – |
| Proportion of variance for HYS | 0.07 ± 0.005 | 0.06 ± 0.004 | 0.08 ± 0.004 |
| Proportion of residual variance | 0.79 ± 0.010 | 0.76 ± 0.009 | 0.77 ± 0.010 |
| Correlation | –0.36 ± 0.339 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 2.95 ± 0.018 | 2.94 ± 0.019 | 2.99 ± 0.019 |
| Heritability | 0.14 ± 0.006 | 0.13 ± 0.005 | 0.13 ± 0.005 |
| Proportion of variance for SS | 0.02 ± 0.002 | 0.02 ± 0.002 | – |
| Proportion of variance for PE | 0.04 ± 0.005 | 0.04 ± 0.005 | 0.04 ± 0.005 |
| Proportion of variance for HYS | 0.04 ± 0.003 | 0.04 ± 0.002 | 0.05 ± 0.002 |
| Proportion of residual variance | 0.77 ± 0.005 | 0.76 ± 0.005 | 0.77 ± 0.005 |
| Correlation | –0.15 ± 0.221 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Table 5. Estimates of genetic parameters (± standard error) for the number of piglets born in the Czech Landrace breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 4.44 ± 0.073 | 4.43 ± 0.087 | 4.50 ± 0.081 |
| Heritability | 0.18 ± 0.010 | 0.17 ± 0.017 | 0.17 ± 0.012 |
| Proportion of variance for SS | 0.02 ± 0.004 | 0.02 ± 0.006 | – |
| Proportion of variance for HYS | 0.05 ± 0.007 | 0.05 ± 0.008 | 0.05 ± 0.007 |
| Proportion of residual variance | 0.80 ± 0.013 | 0.76 ± 0.016 | 0.77 ± 0.013 |
| Correlation | –0.42 ± 0.165 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 5.25 ± 0.061 | 5.24 ± 0.059 | 5.33 ± 0.065 |
| Heritability | 0.20 ± 0.008 | 0.19 ± 0.009 | 0.19 ± 0.010 |
| Proportion of variance for SS | 0.02 ± 0.003 | 0.02 ± 0.003 | – |
| Proportion of variance for PE | 0.05 ± 0.009 | 0.04 ± 0.009 | 0.04 ± 0.009 |
| Proportion of variance for HYS | 0.03 ± 0.004 | 0.03 ± 0.004 | 0.04 ± 0.004 |
| Proportion of residual variance | 0.81 ± 0.008 | 0.73 ± 0.008 | 0.74 ± 0.009 |
| Correlation | –0.87 ± 0.099 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Table 6. Estimates of genetic parameters (± standard error) for the number of piglets born alive in the Czech Landrace breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 3.68 ± 0.081 | 3.68 ± 0.078 | 3.74 ± 0.078 |
| Heritability | 0.17 ± 0.016 | 0.16 ± 0.015 | 0.16 ± 0.015 |
| Proportion of variance for SS | 0.02 ± 0.006 | 0.02 ± 0.006 | – |
| Proportion of variance for HYS | 0.08 ± 0.009 | 0.07 ± 0.008 | 0.08 ± 0.009 |
| Proportion of residual variance | 0.79 ± 0.017 | 0.75 ± 0.016 | 0.76 ± 0.016 |
| Correlation | –0.50 ± 0.410 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 4.28 ± 0.051 | 4.27 ± 0.050 | 4.34 ± 0.053 |
| Heritability | 0.19 ± 0.010 | 0.18 ± 0.009 | 0.18 ± 0.010 |
| Proportion of variance for SS | 0.02 ± 0.003 | 0.02 ± 0.003 | – |
| Proportion of variance for PE | 0.04 ± 0.008 | 0.03 ± 0.009 | 0.03 ± 0.009 |
| Proportion of variance for HYS | 0.05 ± 0.005 | 0.04 ± 0.005 | 0.05 ± 0.005 |
| Proportion of residual variance | 0.79 ± 0.009 | 0.73 ± 0.009 | 0.74 ± 0.008 |
| Correlation | –0.72 ± 0.419 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Table 7. Estimates of genetic parameters (± standard error) for the number of piglets weaned in the Czech Landrace breed

| Genetic parameter | SS with **A** | SS without **A** | Without SS |
|---|---|---|---|
| **Estimates for the first litter** | | | |
| Residual variance | 2.63 ± 0.048 | 2.62 ± 0.052 | 2.67 ± 0.056 |
| Heritability | 0.14 ± 0.015 | 0.13 ± 0.014 | 0.13 ± 0.015 |
| Proportion of variance for SS | 0.02 ± 0.005 | 0.02 ± 0.006 | – |
| Proportion of variance for HYS | 0.09 ± 0.009 | 0.08 ± 0.009 | 0.10 ± 0.009 |
| Proportion of residual variance | 0.79 ± 0.015 | 0.76 ± 0.015 | 0.77 ± 0.016 |
| Correlation | –0.47 ± 0.376 | – | – |
| **Estimates for the second and subsequent litters** | | | |
| Residual variance | 2.88 ± 0.036 | 2.86 ± 0.031 | 2.92 ± 0.034 |
| Heritability | 0.13 ± 0.008 | 0.13 ± 0.008 | 0.13 ± 0.010 |
| Proportion of variance for SS | 0.02 ± 0.003 | 0.02 ± 0.003 | – |
| Proportion of variance for PE | 0.05 ± 0.008 | 0.05 ± 0.008 | 0.04 ± 0.009 |
| Proportion of variance for HYS | 0.06 ± 0.005 | 0.06 ± 0.005 | 0.06 ± 0.006 |
| Proportion of residual variance | 0.75 ± 0.008 | 0.75 ± 0.008 | 0.76 ± 0.008 |
| Correlation | 0.05 ± 0.165 | – | – |

SS = service sire, **A** = relationship matrix, PE = permanent environmental effect of the sow, HYS = herd-year-season effect, Correlation = correlation between the additive genetic effect of the sow and the additive genetic effect of the service sire

Negative correlations were estimated between the additive genetic effects of the sow and those for service sire for litter size traits. In Czech Large White, the values of these correlations were in the range from –0.08 to –0.36, but standard errors were high (0.196 to 0.339) and none of them was significantly different from zero. In Landrace, higher correlations were estimated (up to –0.87) which significantly differed from zero for the number of piglets born. The correlations were the lowest for the number of piglets weaned.

The genetic correlations for litter size traits between the first litter and the second and subsequent litters were approximately between 0.70 and 0.80 in Czech Large White and between 0.95 and 1.00 in Czech Landrace (Table 8). The correlations between the first litter and the second and subsequent litters referring to the service sire were around 0.80 in both breeds.

Table 8. Estimates of genetic correlations, correlations caused by the service sire and correlations for the herd-year-season effect (± standard error) between the first and the later litters; results for the two-trait model without relationship matrix for service sires

| Trait | Genetic correlation | SS correlation | HYS correlation |
|---|---|---|---|
| **Czech Large White** | | | |
| Number born | 0.81 ± 0.023 | 0.85 ± 0.051 | 0.65 ± 0.056 |
| Number born alive | 0.80 ± 0.019 | 0.82 ± 0.038 | 0.73 ± 0.046 |
| Number weaned | 0.71 ± 0.026 | 0.76 ± 0.057 | 0.83 ± 0.027 |
| **Czech Landrace** | | | |
| Number born | 1.00 ± 0.000 | 0.84 ± 0.157 | 0.98 ± 0.096 |
| Number born alive | 0.97 ± 0.032 | 0.88 ± 0.139 | 0.96 ± 0.059 |
| Number weaned | 0.95 ± 0.036 | 0.78 ± 0.124 | 0.99 ± 0.040 |

SS = service sire, HYS = herd-year-season

Table 9. Change (in %) of the average standard error of the predicted breeding values when including the service sire as a random factor without the relationship matrix in the model

| Trait | Parity | Czech Large White | Czech Landrace |
|---|---|---|---|
| Number born | 1 | −1.45 | +0.05 |
| | ≥2 | +0.21 | −0.42 |
| Number born alive | 1 | −1.33 | +0.62 |
| | ≥2 | +0.01 | −0.21 |
| Number weaned | 1 | −1.61 | −0.32 |
| | ≥2 | +0.04 | −1.23 |

Table 10. Literature estimates for the proportion of variance in the number of piglets born alive attributable to service sire

| Authors | Number of litters | Variance ratio for the service sire | | Remarks |
|---|---|---|---|---|
| | | with **A** | without **A** | |
| Woodward et al. (1993) | 61 596 | 0.05 | | Yorkshire |
| See et al. (1993) | 13 537 | 0.02 | | Hampshire |
| | 10 822 | 0.02 | | Landrace |
| Götz (1997) | 37 855 | 0.006 | | Landrace |
| van der Lende et al. (1999) | 7 901 | 0.03 | | Boar line |
| | 22 907 | 0.01 | | Sow line |
| van Steenbergen et al. (2000) | 25 899 | 0.04 | | Sire line |
| Chen et al. (2003) | 251 296 | | 0.04 | Yorkshire |
| | 75 262 | | 0.03 | Duroc |
| | 83 332 | | 0.02 | Hampshire |
| | 53 234 | | 0.04 | Landrace |
| Hamann et al. (2004) | 10 033 | 0.050 | | Landrace, 1st litter |
| | 38 544 | 0.027 | | 2nd and subsequent litters |
| | 6 119 | 0.050 | | Piétrain, 1st litter |
| | 16 884 | 0.031 | | 2nd and subsequent litters |
| Holm et al. (2004) | 6 717 | 0.02 | | Landrace, Landrace ×Yorkshire |
| Ehlers et al. (2005) | 14 583 | | 0.044 | Crossbred sows |
| Lewis et al. (2005) | 5 709 | 0.005 | | Large White, natural service |
| | 22 835 | 0.04 | | Large White, AI |
| | 19 045 | 0.006 | | Landrace, natural service |
| | 23 278 | 0.014 | | Landrace, AI |
| Su et al. (2007) | 9 310 | 0.022 | 0.031 | Landrace |
| | 6 861 | 0.047 | 0.012 | Yorkshire |
| Köck et al. (2009) | 58 925 | 0.00 | | Large White |
| | 17 846 | 0.02 | | Landrace |

For Lewis et al. (2005), approximate numbers of litters were calculated from the total number of litters and the proportions of AI and natural service given by the authors
**A** = relationship matrix

The impact of including the service sire in the model for genetic evaluation on the precision of the predicted breeding values is summarized in Table 9. The numbers given in Table 9 represent the change in percentages of the mean of the standard errors of prediction over all animals born in the most recent years (2005 to 2008) when adding the service sire as a factor to the original model without service sire. If the values are negative the standard error of predicted breeding values decreased on average so that the precision of breeding values increased.

All changes were relatively low. Consistent results for all litter size traits were achieved for the Czech Large White breed where the service sire decreased the standard errors of prediction by approximately 1.5% in the first parity. The influence of the service sire on the precision of breeding values was near zero for all three litter size traits referring to the second and subsequent litters.

The changes in Czech Landrace were mostly less than 1% and did not show systematic differences between the first and the second and subsequent parities as in Czech Large White.

The estimation of genetic parameters from the subsets of data with AI-litters only showed essentially the same results as achieved for the complete data set. Especially there was no change in the proportion of variance for the service sire. Though large changes occurred in the estimates of correlations between the additive genetic effects of the sow and those for service sire, the large standard errors of the correlations showed the changes cannot be proven to be statistically significant.

## DISCUSSION

### Modelling the service sire effect

Service sire effects on litter size traits have been modelled in different ways. Hanenberg et al. (2001) considered this effect to be fixed. Most investigations, however, treat the service sire effect as random. Whereas Hamann et al. (2004) and Lewis et al. (2005) took account of the relationship matrix between animals, Chen et al. (2003) did not make use of this matrix in their calculations. When considering the relationship matrix, a joint matrix for sows and boars has generally been defined. In contrast to this most common procedure, Woodward et al. (1993) constructed separate relationship matrices for sows and boars.

The models published in Serenius et al. (2003), Su et al. (2007), and Köck et al. (2009) simultaneously contain two service sire effects – one with the relationship matrix and one without the relationship matrix. The latter one was termed a permanent environmental effect of the service sire. According to our opinion, that effect would only be formally similar to the permanent environmental effect of the sow. Litter traits are generally considered as sow traits. The sow influences the litter both before and after farrowing through permanent environmental effects. However, environmental effects of the boar on the litter are difficult to explain, especially when artificial insemination is used. Therefore, any service sire effect is expected to be mainly of genetic nature. For this reason, it is difficult to justify why two service sire effects should be included in a model.

If, therefore, one service sire effect in a model should be sufficient, the question is whether it should or should not include consideration of the relationship matrix. Our calculations indicate that both models would yield similar results. If the service sire effect is considered solely as an extraneous effect that should be adjusted for, then the sire effect model without relationship matrix would be adequate. It would have the advantage of being numerically more feasible for routine genetic evaluation than the model taking the relationship matrix between service sires into account. However, in some cases it may be desirable to use the model including the relationship matrix, especially when service sires themselves are to be evaluated.

Recently several investigations have been published on candidate genes for boar fertility and sperm quality (Lin et al., 2006; Gunawan et al., 2011; Kaewmala et al., 2011). It can be expected that these results will influence the selection of AI boars in the future as well as the way the effect of the service sire will be modelled.

### Importance of the service sire effect

Only papers analyzing at least 5000 litters will be taken into account when discussing the results from the literature. Proportions of variance in the number of piglets born attributable to service sires have varied from 0.00 to 0.05 for models including the relationship matrix and from 0.00 to 0.03 for models without the relationship matrix (van der Lende et al., 1999; Serenius et al., 2003; Su et al., 2007; Köck et al., 2009).

Many papers have reported service sire effects for the number of piglets born alive. A summary of published estimates of the proportion of variance for the service sire effect is shown in Table 10. The 20 estimates from models taking the relationship matrix between animals into consideration ranged from 0.00 to 0.05 with a median of 0.02. Only seven estimates were available from models without the relationship matrix. They ranged from 0.00 to 0.04 with a median of 0.03.

Taking the relationship matrix among animals into account, Su et al. (2007) estimated a proportion of variance for service sire of approximately 0.02 both for Yorkshire and Landrace for the number of piglets weaned whereas Köck et al. (2009) reported values of 0.00 for Large White and 0.03 for Landrace. When the relationship matrix was not taken into account, Su et al. (2007) reported an estimate of 0.04 for Landrace and 0.02 for Yorkshire. Chen et al. (2003), when analyzing very large data sets from the Yorkshire, Duroc, Hampshire, and Landrace breeds, found values from 0.03 to 0.05 for the variance ratio of the service sire.

Our results are in agreement with published results that service sires have only a minor impact on litter size traits. Therefore, including the service sire effects in models for breeding value estimation of litter traits will have only a small effect on the precision of the breeding values as shown in our investigation. Under the recent conditions of the Czech selection program for pigs, only the number of piglets born alive in the second and subsequent litters is considered in the selection index and the number of piglets born alive in the first litter is used only as additional source of information via genetic correlation in the breeding value estimation. In this special case the inclusion of the service sire in the model for genetic evaluation will be unnecessary.

### Genetic correlations between the service sire effect and the effect of the sow

Even though the number of observations (litters) was very high in our study, estimates of the genetic correlations between the service sire effect and the effect of the sow were associated with very high standard errors. Repeating the calculations on subsets including AI-litters only showed furthermore that the correlation estimates are very unstable and probably of no relevance. This is in agreement with Serenius et al. (2003) who stated that because of high standard errors of estimates and between-breed differences in their results, there was no clear relationship between direct genetic and service sire effects. Also the estimates of Hamann et al. (2004) did not differ significantly from zero. Van der Lende et al. (1999), van Steenbergen et al. (2000), and Su et al. (2007) did not publish standard errors of their estimates.

The pertinent question is therefore whether the correlation between the sow effect and the service sire effect should be part of the model for (co)variance component and breeding value estimation. It can be expected that the data structure for estimating these correlations will always be far from optimum and that estimates may be strongly biased and unrealistic. Because the service sire effect like that is relatively small, the inclusion of the full relationship matrix in the model might cause numeric problems.

So, if there are good reasons to include the service sire effect into the model for breeding value estimation (what could not be shown for the Czech breeding program), models in which the service sire effect is a simple random effect without inclusion of the relationship matrix should be used. Because of the generally low effect of the service sire this is only recommended if the information on the service sire is available at no additional cost and if addition of service sire to the model for breeding value estimation is computationally feasible.

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