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GENOTYPE BY TEMPERATURE GROUPING INTERACTION FOR FARROWING RATE AT FIRST INSEMINATION

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SUMMARY

This study examined the effect of temperature grouping (T-group) on genetic parameters for farrowing rate from first insemination (FR). Further, this study investigated if genotype by T-group interaction for FR exists. The lowest FR was observed in T-group 1 and 3, which were both characterised by high mean maximum temperature (>29ºC) prior to mating. The heritability of FR across all T-groups differed only marginally from each other and were low (0.03, 0.00, 0.03, 0.02, and 0.03 for T-group 1, 2, 3, 4 and 5, respectively). Genetic correlations between FR recorded in different T-groups were generally positive and high (>0.70), with the exception of the genetic correlation for FR between T-group 1 and 5 which was lowly negative and close to zero (-0.10±0.27). This is an indication that FR in T-group 1 and T-group 5 were two genetically different traits and should be treated as separate traits in pig breeding programs.

INTRODUCTION

Seasonal infertility in pigs has been described as a reduction in reproductive performance during late summer and early autumn (Love 1978). In domestic pigs, seasonal infertility seems to be mainly explained by changes in photoperiod, but can be elevated or alleviated by multiple factors, such as heat stress or management strategies (for example shed cooling systems) (Auvigne *et al.* 2010). The heat stress component of seasonal infertility is becoming more important in Australia, as severity and frequency of extreme heat events have increased across large parts of the country (Whetton *et al.* 2011). Since environmental modification and management seem unlikely to eliminate all heat stress effects or their consequences for seasonal infertility, selection for reduced seasonal infertility in pigs should be explored.

Seasons are classically defined by grouping calendar months according to specific climate characteristics. Most studies have used the classic definition of season to analyse seasonal differences in reproduction performance (Lewis and Bunter 2011). However, seasonal variation may not be well described by this classic definition of season and a more flexible approach is required. A methodology has been developed using cluster analysis to define temperature groupings (T-group) influencing farrowing rate (Bunz *et al.* 2019). These T-groups accounted for different maximum temperature histories that sows were exposed to around mating events. Farrowing rate is an indicator trait for seasonal infertility.

The objective of this study was to investigate the effect T-groups had on genetic parameters for farrowing rate (FR) at first insemination and if genotype by T-group interactions exist for FR.

MATERIALS AND METHODS

Mating data and outcomes from two maternal lines (Large White and Landrace origin) and one terminal line (Duroc origin) were collected from a single farm in southern New South Wales, Australia. The climate is characterised by very hot summers, cool winters and low humidity. The full pedigree information was used, extending over 18 generations. Data included 36,767 FR records of 17,090

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sows (daughters of 977 sires) from the first insemination event within each mating cycle (FR: 0=fail, 1=pregnant) collected from 2012 to 2017. The data set was limited to records from the first three parities of sows. All mating events were performed using artificial insemination, with each sow receiving 2 inseminations of the same boar's semen, supplied from a single boar stud. Boars were housed in sheds with an evaporative cooling system and their semen had to pass quality-control checks before use. Sows were housed in naturally ventilated sheds and had drip cooling provided during their lactation period when shed temperature exceeded 30°C. The following steps outlined further in Bunz *et al.* (2019) were applied for defining 5 T-groups (n = 5): a) a generalized linear model with a logit link was used to identify the most informative days (p-value<0.05) for FR at first insemination regarding maximum ambient temperature (Tmax) in the time period 35 days prior to and 35 days post mating date; b) for every mating date the Tmax of significant days were extracted; and, c) a cluster approach based on partitioning around medoids (PAM; Kaufmann and Rousseeuw 1990) methods was applied to group temperature patterns for every mating date according to their similarity. Parameter estimates for each trait were obtained using an animal model applying ASREML (Gilmour *et al*. 2014). Using a general formulation, the model for FR at first insemination was:

$$y_{ik} = \boldsymbol{X}\beta + \boldsymbol{Z}_1 a_i + \boldsymbol{Z}_1 p_i + \boldsymbol{Z}_3 s_k + e_{ik} \,(\mathbf{1})$$

where y_{ik} y_{ik} ae observations for the *i*th animal inseminated by the *k*th service sire, $\boldsymbol{X}$ is an incidence matrix of factors (β). $\boldsymbol{Z}_1$ is the incidence matrices relating records to additive genetic and permanent environment effects and, $\boldsymbol{Z}_3$ is the incidence matrices relating records to service sire effect, and *a, p* and *s* are vectors of additive genetic, permanent environment and service sire effects, respectively. Significant systematic effects included first insemination year-quarter (24 levels, contemporary groups), breed (3 levels) and sow parity (3 levels). Effects were distributed as $Var(a) = \boldsymbol{A}\sigma_a$, where $\boldsymbol{A}$ is the numerator relationship matrix, $Var(p) = \boldsymbol{I}\sigma_p$, $Var(s) = \boldsymbol{I}\sigma_{service\ sire}$ and $Var(e) = \boldsymbol{I}\sigma_e$ where $\boldsymbol{I}$ is an identity matrix.

To investigate the genotype by T-group interaction data on FR was subsequently split into five traits based on T-group at first insemination, as outlined by Bunz *et al.* (2019). Estimates of genetic correlations between FR in each T-group were then obtained from a series of bivariate analyses. For the bivariate analysis only one record per season per sow was kept avoiding multiple records per sow in one season, leading to 34,838 records. The permanent environment effect of the sow was therefore not fitted in bivariate analyses.

RESULTS AND DISCUSSION

The lowest mean FR was observed in temperature group 1 and 3, which were both characterised by high maximum temperature prior to mating (Table 1). Observation in T-groups were independently distributed from season of the year (Table 2). This study found low heritabilities for FR (Table 3), similar to those reported by Sevillano *et al*. (2016). Farrowing rate was not heritable in T-group 2. However, heritability estimates for FR differed only marginally between T-groups.

Further, the phenotypic variance and the ratio between service sire variance and phenotypic variance was larger in more stressful environments (T-groups 1 and 3) than in less stressful environments (T-groups 2,4,5), which is consistent with results from Sevillano *et al.* (2016).

Estimates of genetic correlations between the same trait recorded in different T-groups are shown in Table 5. The standard errors for genetic correlations were high due to the low heritability in T-group and partially low representation of sows and sire of sows across T-groups (Table 4). Further, it was not possible to estimate genetic correlations between T-group 2 and other T-groups due to non-existence of additive genetic variation in T-group 2. The genetic correlations between FR recorded in different T-groups were high with one exception; the genetic correlation between T-group 1 and 5. This genetic correlation was negative and close to zero, suggesting the existence of a genotype by temperature grouping interaction. T-group 1 and T-group 5 were the opposite in the maximum temperature characteristics, which is a possible explanation for the low genetic correlation for farrowing rate at first insemination between these two T-groups. Sevillano *et al*. (2016) found a higher genetic correlation (0.76±0.19) of FR between opposite environments (stressful and non-stressful) using a bivariate model.

Table 1. Data characteristics for farrowing rate according to temperature group (T-group)

T-group	Temperature characteristics of T-group	n records	n sows	Mean (sd)	CV
1	high prior and post mating	8686	8080	0.77 (0.42)	54.6
2	low prior and medium post mating	6989	6648	0.85 (0.35)	41.5
3	high prior and medium post mating	5471	5399	0.75 (0.43)	57.5
4	medium prior and low post mating	5204	5093	0.84 (0.37)	44.2
5	low prior and post mating	10411	9618	0.86 (0.34)	40.0

Abbreviations: Mean Maximum temperature characteristics: high >29ºC; medium 21-29°C; low <21ºC

Table 2. Distribution of records across T-groups and season

T-group	n records	Summer (Jan-Mar)	Autumn (April-Jun)	Winter (July-Sept)	Spring (Oct-Dec)
1	8686	4859			3827
2	6989	31		1377	5581
3	5471	4190	1152		129
4	5204	48	5081	39	36
5	10411		2766	7434	211

Table 3. Estimates of variances due to additive genetic (σ^2_a) and service sire effects on farrowing rate, along with the residual (σ^2_e) and phenotypic (σ^2_p) variances and ratios of heritability (h^2: se in brackets) or service sire effects by temperature grouping (T-group)

T-group	σ^2_a	σ^2_{pe}	σ^2_{ss}	σ^2_e	σ^2_p	h^2	pe^2	ss^2
1	0.0051	0.0101	0.0041	0.1550	0.1642	0.0311 (0.012)	0.0615 (0.053)	0.0252 (0.006)
2	0.0000	0.0080	0.0026	0.1128	0.1154	0.000 (0.000)	0.0693 (0.069)	0.0223 (0.006)
3	0.0050	0.0071	0.0037	0.1677	0.1763	0.0284 (0.017)	0.0407 (0.112)	0.0208 (0.007)
4	0.0023	0.0000	0.0012	0.1321	0.1356	0.0172 (0.017)	0.0000 (0.000)	0.0086 (0.006)
5	0.0031	0.0000	0.0010	0.1139	0.1179	0.0261 (0.099)	0.0000 (0.000)	0.0085 (0.004)

Abbreviations: $h^2 = \sigma^2_a/\sigma^2_{p;}$ $pe^2 = \sigma^2_{pe}/\sigma^2_p$; $ss^2 = \sigma^2_{ss}/\sigma^2_p$

The current study focused only on the temperature component of seasonal infertility. However, the methodology can be further developed accounting also for the photoperiod component. The presence of genotype by T-group interaction can be explore for other traits.

Table 4. Number of sows by temperature grouping (T-group) on the diagonal; the number of sows in common between T-group above the diagonal, the number of sire of sows in common between T-group below the diagonal

T-group	1	2	3	4	5
1	8080	1827	1310	2153	5415
2	437	6648	2226	2669	2392
3	332	494	5399	695	3279
4	495	545	254	5093	1656
5	672	541	612	436	9618

Table 5. Genetic correlations (above diagonal), residual correlations (below diagonal 1st row) (SE) and phenotypic correlations (below diagonal 2nd row) and for farrowing rate at first insemination between temperature groupings (T-group)

T -group	1	3	4	5
1		0.82(0.23)	0.85(0.48)	-0.10(0.27)
3	0.00(0.04) 0.04(0.03)		0.98(0.55)	0.79(0.34)
4	0.09(0.03) 0.11(0.03)	0.04(0.05) 0.07(0.04)		0.89(0.39)
5	0.03(0.02) 0.03(0.02)	-0.03(0.02) 0.00(0.02)	0.04(0.03) 0.00(0.03)	

CONCLUSIONS

This study was able to show that genotype by T-group interactions exist for FR, which is a trait used to indicate seasonal infertility. Farrowing rates observed in T-group 1 and 5, which were characterised by opposite mean temperature patterns around mating events, were genetically two different traits. The results of this study show that using trait-specific T-groups can provide an opportunity to improve the heat stress component of seasonal infertility in pigs genetically. Additionally, this methodology can be extended to include photoperiod information and applied to other reproduction traits.

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