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Crossbreeding parameters for fertility traits in a rotational crossbreeding between Landrace and Piétrain pigs*

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Abstract: The reproduction characteristics of 343 sows in six different breeding groups were analyzed to estimate the crossbreeding parameters. The results indicated that the ovulation rate and the weights of uterus and ovary are mainly determined by the additive genetic effects while the nonadditive genetic effects play an important role in embryonal traits and litter performance. The heterosis effects in the first litter are larger than those in the second litter because of heterosis x environment interaction. The results also showed the existence of a highly significant maternal heterosis effect on the fertility traits of sows.

Key words: Landrace pig, Piétrain pig, Crossbreeding parameter, Fertility traits
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INTRODUCTION

Rotational crossbreeding is specially useful under unfavorable hygienic and infrastructural conditions, and allows for optimum utilization of individual and maternal heterosis effects of the dam as well as the individual, maternal and grand maternal heterosis effects of the piglets, beside an appropriate combination of the breed effects. Information available on the realization of these crossbreeding parameters in specific rotational crossbreeding programs is very scanty. Hence, this investigation was conducted to evaluate the possible significance of the above effects from a long term rotational crossbreeding program between two complementary breeds, Landrace, known for its fast growth rate and Piétrain, famous for its muscling ability.

MATERIAL AND METHODS

The analysis was carried out on 343 sows, consisting of purebred Landrace (63), Landrace to be mated with Piétrain (38), purebred Piétrain (40), their F_1 crosses (48) and rotational groups with Landrace (79) and with Piétrain (75). During the first two parities, the size and weights of the litters were recorded, while in the third parity, four weeks after successful mating, the sows were slaughtered and their uteri and ovaries were weighed and the number of corpus luteum and embryos were counted. The embryonal survival rate was directly calculated from the number of live embryos of 28 days post coitus and ovulation rate. The trait was defined in this way because most of the embryonal losses occurred during the first month of the pregnancy (Bolet, 1986a) and as the swine has a very high fertilization rate (Perry et al., 1962).

The analysis was conducted in two steps (Fu, 1995; 1998). At first, the breeding group means were estimated with a mixed model:

$$\boldsymbol{y} = X\boldsymbol{b} + Z_1\boldsymbol{a} + Z_2\boldsymbol{s} + \boldsymbol{e}$$

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Where, $\boldsymbol{y}$ is a vector of phenotypic performance and b is a vector of the fixed effects including those due to breeding groups, years, seasons, age of the dam, type of mating and the significant interactions between them. The random effects due to the animal (the sow effects for embryos or piglets), sire and error are included in vectors $\boldsymbol{a}$, $\boldsymbol{s}$ and $\boldsymbol{e}$, respectively. Z_1 and Z_2 are the respective design matrices. The crossbreeding parameters were estimated in a second step after the estimation of the breeding group means (vector $\hat{\boldsymbol{r}}$) and the variance-covariance matrix (V). The model was:

$$\hat{\boldsymbol{r}} = K\boldsymbol{g} + \boldsymbol{e}$$

The design matrix K was constructed according to Dickerson's model. Here, the Piétrain was considered as the base for comparison. The crossbreeding parameters consisted of individual and maternal additive genetic effect (g_i and g_m) as well as respective heterosis effects (h_i and h_m). These (vector $\boldsymbol{g}$) were estimated with Generalized Least-Squares procedure (GLS) using the following equation:

$$KV^{-1}K\hat{\boldsymbol{g}} = KV^{-1}\hat{\boldsymbol{r}}$$

RESULTS

1. Rates of ovulation and embryonal survival

The estimates of the crossbreeding parameters for ovulation rate, number of embryos and embryonal survival rate are given in Table 1. All these parameters have a positive effect on the four traits except the maternal additive genetic effect for ovulation rate and for number of total and live embryos. There were highly significant individual and maternal additive genetic effects for ovulation rate. They were almost of the same magnitude but in different directions. On the contrary the other traits relating to embryo were more affected by individual heterosis which were significant for number of total embryos (1.82) and number of live embryos (1.50) and highly significant for embryonal survival rate (8.29%).

Table 1 Estimates of crossbreeding parameters for rates of ovulation and embryonal survival (28 days p.c.)

Parameter	Ovulation rate	Number of embryos	Number of live embryos	Embryonal survival rate (%)
N	281	280	280	280
μ_P	14.07	11.40	10.53	73.27
g_i	1.47***	1.04	1.31*	4.68
g_m	−1.43***	−0.71	−0.87	0.59
h_i	0.40	1.82*	1.50*	8.23**
h_m	0.54	0.41	0.61	3.41

N: Number of sows; μ_P: Overall mean; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

2. Litter size

As usually expected, the individual additive genetic effect and the individual heterosis effects were significant for all the traits of litter size (Table 2). The maternal additive genetic effect was significant for the total number of piglets in the first farrowing, but it was negative. This effect was also significant both in first and second parities for number of piglets weaned, and it was positive. The maternal heterosis effect was significant for total number of piglets as well as number of piglets weaned, and in the first parity was higher than that in the second one.

3. Litter weight

There was hardly any effect of individual additive genetic effect on the litter weight in the first parity but it was significant in the second one (Table 3). The maternal additive genetic effect was highly significant with a large effect on the litter weight at weaning. The individual heterosis effect was significant for litter weight at birth in the first parity, while highly significant for litter weight at weaning in the second parity. The maternal heterosis effect was significant for litter weights at birth as well as weaning and that also for both the parities. The effect was higher in the first parity compared to the second one and specially so for the litter weight at weaning (5.98kg).

Table 2 Estimates of crossbreeding parameters for traits of litters size

Parameter	Numbers of total piglets at birth		Number of live piglets at birth		Number of piglets at weaning	
	1st parity	2nd parity	1st parity	2nd parity	1st parity	2nd parity
N	343	253	341	252	339	249
μ_P	7.78	8.45	6.92	8.18	5.67	7.15
g_i	1.56***	1.76***	1.43**	1.70***	0.54*	0.39**
g_m	−0.89*	−0.29	−0.45	−0.26	0.71**	0.72***
h_i	1.15**	1.02**	1.24**	1.10**	0.54*	0.71***
h_m	1.04*	0.79*	0.91	0.56	1.24**	0.53*

* $P<0.05$; ** $P<0.01$; *** $P<0.001$

Table 3 Estimates of crossbreeding parameters for traits of litter weight (kg)

Parameter	Litter weight at birth		Litter weight at weaning	
	1st parity	2nd parity	1st parity	2nd parity
N	341	253	339	249
μ_P	9.07	11.28	33.44	43.03
g_i	0.45	2.93*	−1.31	6.15**
g_m	0.48	−1.13	7.59*	2.86
h_i	1.21*	0.88	1.86	3.89**
h_m	2.06*	1.46*	5.98*	2.85*

* $P<0.05$; ** $P<0.01$

4. Weights of uterus and ovary

These traits appear to be determined mainly through additive genetic effects (Table 4). The individual additive genetic effect was significant for both uterus and ovary weights although it was negative for the former. No significant heterosis effect was observed for these traits although in general, the maternal heterosis was higher.

Table 4 Estimates of crossbreeding parameters for weights of uterus and ovary

Parameter	Uterus weight(g)	Ovary weight(g)
N	280	279
μ_P	3700	14.73
g_i	−387*	1.58**
g_m	122	−0.93
h_i	36	−0.29
h_m	221	0.45

* $P<0.05$; ** $P<0.01$

DISCUSSION

It is known that the Landrace has higher fertility than the Piétrain breed. Looking at the components, there is hardly any difference between the ovulation rates of the two breeds. On the other hand, the embryonal survival rate of the Landrace breed is higher (by 5.27%) than that of the Piétrain breed because of the positive individual and maternal additive genetic effects. Similar observations were also reported by Bolet et al. (1986b) and Bazer et al. (1988), who also suggested that the higher fertility in Meishan pigs was not due to higher ovulation rate but due to higher embryonal survival rate. Thus the attempts to induce superovulation did not increase litter size (Polge, 1982). Furthermore, even if selection was practiced for higher ovulation rate, it did not increase the litter size (Cunningham et al., 1979), despite of an intermediate heritability for ovulation rate. Perhaps, a higher rate of ovulation is automatically associated with a higher embryonal mortality due to a limited uterine ability. It was observed that embryonal survival rate had very low genetic foundation, and it was mainly determined by nonadditive genetic effects (Bolet, 1986) as was also seen in the present investigation. Hence an improvement in fertility has still to be attempted through crossbreeding.

An important limiting factor of embryonal survival rate could be the uterine capacity (Wrathall, 1971; Couningham, et al., 1979; Vangen, 1981; Johnson et al., 1984). In the present study, the uterine weight, as an indicator of uterine capacity, was even lower in the Landrace breed compared to the Piétrain breed. On the other hand, if the breed effects were excluded, the embryonal survival rate was positively associated with uterine weights ($r=0.25$). Thus from the comparison across breeds, it seems quite likely that it is not only the uterine capacity that determines the embryonal survival but that the uterine activity might also play an important role.

The ovarian weight was taken as a measure of its activity. A positive relationship ($r=0.24$) was observed between the weight of the ovary and ovulation rate, despite of the fact that it undergoes compensatory hypertrophy after partial ovariotomy and produces almost the same number of eggs as before (Wrathall, 1971). The individual additive genetic effect was higher for this trait but it also seemed to be compensated to some extent by the negative maternal additive genetic effect so that there are no large differences between the two breeds with respect to the ovarian weights and ovulation rates of the two breeds.

A very important observation in this investigation was the significance of individual and maternal heterosis effects. Among them, the individual heterosis effect was more important for embryonal survival and consequently for litter size at birth. On the other hand, the maternal heterosis effect played a more significant role in postnatal survival as well as litter weights at birth and weaning. Thus, more attention is required to exploit the maternal heterosis effect for fertility traits of sows, that means the grand maternal heterosis effects for the embryos and piglets. This can be realized either through crossing of more female lines or through consecutive crossbreeding procedures such as rotational cross breeding. Whereby, the later could be more preferable due to several economic, organizational and hygienic advantages specially for adverse environmental and infrastructural conditions.

References

Bazer, F., Thatcher, W., Martinat-Bolet, F. et al., 1988. Conceptus development in large white and prolific Chinese meishan pigs. *J. Repro. Fert.*, **84**: 37–42.

Bolet, G., 1986a. Timing and extent of embryonic mortality in pigs. *In*: Embryonic mortality in farm animals. A seminar in the CEC programme, Dordrecht, Netherlands. p. 12–43.

Bolet, G., Martinat-Botte, F., Locatelli, P. et al., 1986b. Components of prolificacy in hyperprolific Large White sows compared with the Meishan and Large White breeds. *Génét. Sél. Evol.*, **18**: 333–342.

Cunningham, P. J., England, M. E., Young, L. D. et al., 1979. Selection for ovulation rate in swine: correlated response in litter size and weight. *J. Anim. Sci.*, **48**: 509–516.

Fu, Y., 1995. Schaätzung von Kreuzungsparametern für Reproduktionsmerkmale bei einer Rotationskreuzung zwischen Schweinen der Rassen Pietrain und Deutsche Landrasse. Verlag Koester, Berlin, ISBN3-89574-054-3.

Fu, Y., 1998. Methodological improvement in estimation of crossbreeding parameters. *In*: Advanced Topics in Biomathematics, World Scientific, Singapore, 47–52.

Johnson, R. K., Zimmerman, D. R., Kittok, R. J., 1984. Selection for components of reproduction in swine. *Livest. Prod. Sci.*, **11**: 541–558.

Perry, J. S., Rowlands, I. W., 1962. Early pregnancy in the pig. *J. Reprod. Fert.*, **4**: 175–188.

Polge, C., 1982. Embryo transplantation and preservation. *In*: Control of Pig Reproduction. Butterworths Scientific, London, p. 479–506.

Vangen, O., 1981. Problems and possibilities for selection for fecundity in multiparous species. *Pig News and Information*, **2**: 257–263.

Wrathall, A. E., 1971. Prenatal survival in pigs. Part 1. Ovulation rate and its influence on prenatal survival and litter size in pigs. The Gresham Press, Old Working, England.