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ESTIMATES OF BREED AVERAGE DIRECT, MATERNAL AND HETEROSIS EFFECTS FOR SOME PRODUCTIVE TRAITS OF SWINE IN THE MEXICAN TROPICS

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ABSTRACT

Records from 2985 purebred and crossbred litters farrowed in a commercial farm in the southeast of Mexico were analyzed. A multiple regression procedure was used to obtain estimates of breed average direct, breed maternal, and direct and maternal heterosis effects for the Duroc (D), Hampshire (H), American Landrace (L) and Yorkshire (Y) breeds and their crosses. Average direct and maternal effects were expressed as deviations from the Y breed. Average direct effects for litter size and weight at birth and litter size at weaning did not differ significantly among breeds although, in general, the Y breed was the best. Landrace average effect for litter weight at weaning was large and significant ($P < 0.05$). Breed maternal effects for all preweaning traits were in general small for the D and H breeds, but large and significant for the L breed ($P < 0.05$). Direct and maternal heterosis effects were in general significant ($P < 0.05$) for litter size and weight at weaning.

INTRODUCTION

Large breed differences in direct and maternal genetic effects are evident for most economically important traits in swine (Johnson, 1981). These genetic differences can lead to large economic differences among various crossing systems, differences that depend on the breeds involved and the percentage of the heterosis utilized by the system (Johnson, 1981). Thus, in order to plan sound breeding programmes, it is necessary to know the kind of gene action (additive or nonadditive) and the maternal contribution to the performance of the offspring (Dillard *et al.*, 1980; Jungst and Kuhlers, 1984).

The mean performance of breed and breed crosses in terms of direct and maternal average effects of breeds, individual and maternal heterosis components were defined by Dickerson (1973) and the estimation of these parameters by multiple regression approach by Dillard *et al.* (1980) in beef cattle and Jungst and Kuhlers (1984) in swine.

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In Mexico, purebred stock has its origin in imports from the United States and Canada. Breeds such as Duroc, Hampshire, American Landrace and Yorkshire are used commonly in swine crossbreeding programs. Among these four breeds more than one hundred possible breed combinations could be produced, all sired by purebred boars. Because it would not be economically feasible to evaluate each cross, one approach would be to estimate genetic parameters which could be used to predict the performance of each cross, and thus to choose the best system and breeds for crossing (Quintana and Robison, 1983; Jungst and Kuhlers, 1984).

Estimates of average direct, maternal and heterosis effects for swine have been obtained for USA conditions by Quintana and Robison (1983) and Jungst and Kuhlers (1984). However, to the knowledge of the authors no such estimates exist for swine under tropical conditions.

Litter productivity is one of the most important parameters for evaluating commercial pig production. Some of the common measures generally evaluated are litter size and litter weight at birth and weaning. The objective of the present study was to estimate the breed average, breed maternal, direct and maternal heterosis effects for Duroc, Hampshire, Landrace and Yorkshire breeds for litter size and litter weight at birth and at weaning.

MATERIAL AND METHODS

Source of data, animals and management

Data were obtained on 2985 litters farrowed during a period of nine years on a commercial farm in northern Yucatan state, Mexico. The region has an average rainfall of 515 mm and an average monthly temperature that ranges from a maximum of 27.1°C in June to a minimum of 22.9°C in January.

Purebred gilts used to form the base population came from northern Mexico. Purebred unrelated boars were imported from several farms in the United States. Later importations included purebred gilts and boars from northern Mexico only. The Duroc (D), Hampshire (H), Landrace (L) and Yorkshire (Y) breeds were used to produce 167 different breed groups of litters. Among the 167 combinations four were purebred matings, 12 two-breed static crosses, 15 three-breed static crosses, 11 four-breed static crosses, 13 backcrosses, 8 two-breed rotational crosses, 18 three-breed rotational crosses and 86 other crosses.

During pregnancy, the sows were housed in groups of ten in open houses with pen sizes of 5m x 6m. Feeding during pregnancy consisted of 2.0 kg/day of a commercial gestation diet containing 12% of crude protein (CP), using sorghum and soya as the main ingredients. On day 109 or 110 of pregnancy the sows were moved to the farrowing house and were fed a lactation diet containing 14% CP. Daily allowance was based on litter size (4.0 kg for the sows and 0.4 kg for every piglet over five). Within 24 hours postpartum, the pigs were identified and weighed and 2 ml of Fe dextran was administered. At approximatelly 21 days of age the pigs were weaned and each litter was counted and weighed. In some cases crossfostering was practiced.

Health status of the herd was in general good. Sows were dewormed twice annually and vaccinated against classical swine fever one week before weaning.

Statistical analysis

During the nine year period of data collection, 596 dams farrowed and litters were sired for 46 D, 14 H, 39 L, and 16 Y unrelated boars. A multiple regression procedure (Dillard *et al.*, 1980, Jungst and Kuhlers, 1984) was used to obtain estimates of the breed average, breed maternal, direct heterosis and maternal heterosis effects for litter size at birth (LSB), number of piglets born alive (NBA), litter weight at birth (LWB), litter size at weaning (LSW) and litter weight at weaning LWW). All litters in which cross fostering occurred were excluded from the analysis.

The following statistical model was used in the analysis of the litter traits:

$$Y_{ijkl} = M + F_i + S_j + P_k + b1\,A_D + b2\,A_H + b3\,A_L + 4\,A_Y + b5\,HD_{DH} + b6\,HD_{DL} + b7\,HD_{DY} + b8\,HD_{HL} + b9\,HD_{HY} + b10\,HD_{LY} + b11\,M_D + b12\,M^H + b13\,M_L + b14\,M_Y + b15\,HM_{DH} + b16\,HM_{DL} + b17\,HM_{DY} + b18\,HM_{HL} + b19\,HM_{HY} + b20\,HM_{LY} + E_{ijkl}$$

where:

Y_{ijkl} = the 1th litter on the kth parity number of the sow for the jth season of farrowing and the ith year of farrowing,

M = least squares mean,

F_i = effect of the ith year of farrowing (i = 1, 2, ... 9),

S_j = effect of the jth season of farrowing (i = 1,2),

P_k = effect of the kth parity number (k = 1, 2, ... 8),

b1, b2, b3, b4 = breed average effects for D, H, L, and Y, respectively.

A_D, A_H, A_L, A_Y = percentage of genes contributed by breeds D, H, L and Y,

b5, b6, b7, b8, b9, b10 = heterosis direct effect due to interaction of any two alleles at the same locus, with the alleles being from breeds D and H, D and L, D and Y, etc.,

HD_{DH}, HD_{DL}, HD_{DY}, HD_{HL}, HD_{HY}, HD_{LY} = percentage of loci occupied by genes from breeds D and H, D and L, D and Y etc.,

b11, b12, b13, b14 = breed maternal effects for D, H, L and Y, respectively,

M_D, M_H, M_L, M_Y = percentage of genes in the dam from breeds D, H, L and Y, respectively,

b15, b16, b17, b18, b19, b20 = maternal heterosis effects due to interaction of any two alleles at the same locus, with alleles coming from different breeds,

HM_{DH}, HM_{DL}, HM_{DY}, HM_{HL}, HM_{HY}, HM_{LY} = percentage of loci in the dam with one gene from one breed and the other gene from a different breed, and

E_{ijkl} = the random error term for the 1th litter on the kth parity number for the jth season of farrowing and the ith year of farrowing.

Since the above model results in a singular matrix, breed average direct and maternal effects for D, H, and L were computed as deviations from Y. After the restrictions were imposed on the matrix, the overall least-squares mean was the least-squares mean was the least-squares mean for the Y breed. As mentioned by Jungst and Kuhlers (1984) it should be emphasized that breed average direct and maternal effects are not independent estimates of the breed parameters, but the relative magnitude of the estimates would be the same regardless of which breed was used to remove the dependencies in the matrix. All results in this study are relative to the performance of the Y breed.

The data were analyzed using general linear model procedures (SAS, 1985).

RESULTS

The analysis of variance (not given) showed significant ($P < 0.01$) effects of year and farrowing number on all preweaning traits, and of season of farrowing only on LWW.

Except for the L additive genetic effect which was large and significant for LWW ($P < 0.05$), the additive effects of the preweaning traits of the D, H and L breeds were nonsignificant (Table I). For maternal effects the D breed had the poorest result for all preweaning traits, followed by the H breed, whereas, the L breed was superior to the Y breed (Table II).

In general, direct heterosis effects, though mostly positive, were not significantly different from zero for the litter traits at birth. However, most of them were significantly different for the weaning traits (Table I). Similarly, the maternal heterosis effects were positive for all traits, except for LSW and LWW of the HL crossbreed, but only some were significant (Table II).

DISCUSSION

In general, the results of this study do not agree with those of Jungst and Kuhlers (1984) who found that the average effects for LSW and LWW of the D and H breeds were smaller than those for the L breed, which in turn was smaller than that for the Y breed. However, in this study and those reported by Jungst and Kuhlers (1984) and Quintana and Robison (1983) the H breed had the lowest average direct values for LSW. Fahmy and Holtmann (1977) have reported that Y sows have larger litters at birth and weaning than the L and D breeds. Differences between these results might be attributed to the base populations used and also to the genetic selection the swine industry is making in these breeds which may change the rank order of the breeds within a few years.

Mating between two breeds generally produces a desirable degree of direct heterotic effect on the litter, especially at weaning (Table I). Contrary to that reported by Jungst and Kuhlers (1984), the white breeds (L and Y), in this study, seem to combine well for weaning traits, as indicated by the significant and positive direct heterosis effects (Table I). The L breed appears to have a greater combining ability than the other breeds for most preweaning traits (Table I). Because of the undesirable

Table I - Breed average direct and heterosis effects ± standard errors for swine litter size and weight at birth and weaning.

	Litter traits[a]				
	LSB	NBA	LWB	LSW	LWW
My[+]	9.88 ± .22	9.65 ± .21	14.6 ± 34	8.56 ± .44	42.6 ± 3.1
Average effect[b]:					
D	-.126 ± .187	-.005 ± .177	-.412 ± .282	-.008 ± .181	-1.04 ± 1.00
H	-.300 ± .311	-.424 ± .295	-.427 ± .469	-.547 ± .302	-3.03 ± 1.66
L	-.227 ± .272	-.188 ± .256	-.371 ± .410	-.117 ± .263	2.85 ± 1.45*
Direct heterosis:					
DH	.270 ± .278	.453 ± .264	1.172 ± .420**	.860 ± .270**	6.56 ± 1.49**
DL	.335 ± .278	.424 ± .263	.993 ± .419*	.861 ± .269**	5.48 ± 1.48**
DY	-.202 ± .163	-.153 ± .154	.377 ± .246	.421 ± .158**	3.76 ± .87**
HL	.640 ± .382	.759 ± .362*	.953 ± .576	.994 ± .370**	4.66 ± 2.03*
HY	.096 ± .319	.196 ± .302	.647 ± .481	.408 ± .309	3.61 ± 1.70*
LY	.505 ± .233*	.519 ± .221*	.861 ± .352*	.855 ± .226**	4.44 ± 1.24**

*$P < 0.05$, **$P < 0.01$.

+ = Least-squares means for the Yorkshire breed.

a) LSB = Litter size at birth, NBA = Number of piglets born alive, LWB = Litter weight at birth, LSW = Litter size at weaning, LWW = Litter weight at weaning.

b) Average effects as deviations from the Yorkshire breed.

Table II - Breed maternal and maternal heterosis effects ± standard erros for some swine litter traits at birth and weaning in the tropical environment of south-east Mexico.

	Litter traits[a]				
	LSB	NBA	LWB	LSW	LWW
Maternal effects[b]					
D	-.311 ± .174	-.379 ± .165*	-.105 ± .263	-.396 ± .168*	-3.75 ± .93**
H	-.169 ± .324	-.170 ± .307	-.412 ± .489	-.078 ± .314	1.14 ± 1.73
L	.181 ± .218	.251 ± .207	.828 ± .330*	.202 ± .211	1.69 ± 1.16
Maternal heterosis[c]					
DH	.408 ± .278	.586 ± .263	.374 ± .419	.705 ± .269**	1.34 ± 1.48
DL	.593 ± .176**	.552 ± .167**	.551 ± .265*	.656 ± .170**	2.96 ± .94**
DY	.707 ± .151**	.680 ± .143**	.821 ± .228**	.703 ± 1.46**	2.84 ± .80**
HL	.354 ± .328	.174 ± .311	.005 ± .495	-.125 ± .318	-1.58 ± 1.75
HY	.614 ± .317	.357 ± .301	1.201 ± .488**	.307 ± .308	1.46 ± 1.69
LY	.191 ± .135	.201 ± .128	.691 ± .205**	.338 ± .130**	2.40 ± .72**

*P < 0.05, **P < 0.01.

a) LSB = Litter size at birth, NBA = Number of piglets born alive, LWB = Litter weight at birth, LSW = Litter size at weaning, LLW = Litter weight at weaning.

b) Average effects as deviations from the Yorkshire breed.

additive and maternal effects of the coloured breeds (especially the D breed) it would be better for the swine industry to use the L and Y breeds as the maternal breeds.

Averaged overall heterosis estimates were derived for each trait in order to be compared with the values from the literature. For example, the value of 0.37 for NBA is the average of values from -0.153 to + 0.759. The mean heterosis values for LSW and LWW (0.71 and 4.75, respectively) are within the range of values reported in the literature (Quintana and Robison, 1983, Schneider *et al.*, 1982; Young *et al.*, 1976 and Johnson, 1981). As mentioned by Johnson (1981), the higher estimates for LSW compare to LSB provide evidence of the importance of heterosis effects on pig survival.

There were clear differences between maternal crosses (Table II). The specific maternal heterosis effects for the crosses among the D, H, L and Y breeds were not the same as the effects reported by Quintana and Robison (1983) for LSW. To develop sound breeding programs it is necessary to know the values for maternal heterosis effects. The lack of these values might change the ranking of the genotypes or crosses compared.

The estimates of average maternal heterosis obtained in this work were lower than the estimates reported in the literature. The average maternal heterosis for LWB in this study was 0.61 kg compared to the 1.00, 1.46 and 2.49 reported by Johnson *et al.* (1978), Schneider *et al.* (1982) and Jungst and Kuhlers (1984), respectively. The estimate of maternal heterosis for LSW (0.43 pigs) is similar to the estimates of 0.56 pigs obtained by Schneider *et al.* (1982), but is lower than other estimates of 0.93 pigs (Johnson, 1981), 1.31 pigs (Johnson *et al.*, 1978) and 1.28 pigs (Jungst and Kuhlers, 1984). On the other hand, maternal heterosis for LWW (1.57 kg) was much lower than the estimates of 8.66 and 5.91 reported in the literature (Schneider *et al.*, 1982; Jungst and Kuhlers, 1984, respectively). Differences in maternal heterosis values found here might be attributed to differences in the base population and some other factors which may alter the relative performance of the breeds and crosses, such as the climate, nutrition or disease exposure (Dickerson, 1969). In addition genotype-environment interactions and heterosis-environment interactions have an important role in the differences in the relative performance of genotypes (Falconer, 1981; Barlow, 1981).

In conclusion, large differences among breeds in average direct, maternal and heterotic effects were evident for most preweaning traits. However, the ranking of breed average and heterotic effects, in this study, was not the same as those previously found under temperate conditions. These differences suggest large economic differences among various crossbreeding systems. From the breed average direct, breed maternal, direct heterosis and maternal heterosis values calculated for D, H, L and Y breeds, it might be possible to predict the reproductive performance of different breed combinations and to perform further evaluations of the better ones under tropical conditions.

RESUMO

Foram analisados registros de 2985 porcos puros e cruzados em uma fazenda comercial no sudeste do México. Usou-se o procedimento de regressão múltipla para a obtenção de estimativas de efeitos genético aditivo de raça, maternal de raça e efeitos diretos e maternais para as raças Duroc (D), Hampshire (H), American Landrace (L) e Yorkshire (Y) e seus cruzamentos. Efeitos aditivos direto e materno foram expressos como desvios da raça Y. Os valores genéticos aditivos para o tamanho e peso dos filhotes ao nascer e tamanho da ninhada à desmama não diferiram significantemente entre raças, embora, em geral, a raça Y foi a melhor. O efeito aditivo do L para o Peso da ninhada ao desmame foi grande e significante (P < 0,05). Efeitos maternais da raça para todas as características pré-desmame foram, em geral, pequenos para as raças D e H, mas grande e significante para a raça L (P < 0,05). Efeitos da heterose direta e materna foram em geral significantes (P < 0,05) para o tamanho da ninhada e peso à desmama.

REFERENCES

Barlow, R. (1981). Experimental evidence for interaction between heterosis and environment in animals. *Anim. Breed. Abstrs. 49*: 715-737.

Dickerson, G.E. (1969). Experimental appraches in utilizing breed resources. *Anim. Breed. Abstrs. 37*: 191-202.

Dickerson, G.E. (1973). Inbreeding and heterosis in animals. In: *Proceedings of the Animal Breeding and Genetic Symposium in honor of J.L. Lush.* ASAS, ADSA and PSA, Champaign, Illinois, pp. 54.

Dillard, E.U., Rodriguez, O. and **Robison, O.W.** (1980). Estimation of additive and non additive direct and maternal genetic effects from crossbreeding beef cattle. *J. Anim. Sci. 50*: 653-663.

Fahmy, M.H. and **Holtman, W.B.** (1977). Crossbreeding swine in Canada. *World Rev. Anim. Prod. 13*: 9-15.

Falconer, D.S. (1981). *Introduction to Quantitative Genetics*. 2nd edn. Longman, London and New York, pp. 340.

Johnson, R.K. (1981). Crossbreeding in swine: Experimental results. *J. Anim. Sci. 52*: 906-923.

Johnson, R.K., Omtvedt, I.T. and **Walters, L.E.** (1978). Comparison of productivity and performance for two-breed and three breed crosses in swine. *J. Anim. Sci. 46*: 69-82.

Jungst, S.B. and **Kuhlers, D.L.** (1984). Estimates of additive genetics maternal and specific combining abilities for some litter traits of swine. *J. Anim. Sci. 59*: 1140-1148.

Quintana, F.G. and **Robison, O.W.** (1983). Systems of crossbreeding in swine. 1. Estimation of genetic parameters. *Z. Tierzuchtg. Zuchtgsbiol. 100*: 271-279.

SAS (1985). *SAS/STAT Guide for personal computers*. Versions 6. SAS Institute, Cary, North Carolina, USA, pp. 378.

Schneider, J.F., Christian, L.L. and **Kuhlers, D.L.** (1982). Crossbreeding in swine: Genetics effects on litter performance. *J. Anim. Sci. 54*: 739-746.

Young, L.D., Johnson, R.K. and **Omtvedt, I.T.** (1976). Reproductive performance of swine breed to produce purebred and two-breed cross litters. *J. Anim. Sci. 42*: 1133-1149.

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