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Effects of Direct Additive and Direct Dominance on Litter Traits in Crossbred Sows between Danish Yorkshire and Danish Landrace Pigs in Vietnam

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ABSTRACT

Background: The objectives of this study were to estimate the effects of direct additive and dominance on litter traits and to predict the reproduction of un-tested crossbred sows between Danish Yorkshire (Y) and Danish Landrace (L) pigs in Vietnam.

Methods: Litter traits data were obtained between 2014 and 2017 in Binh Thang and Khang Minh An breeding farms, with 671 litters of crossbred sows crossed from 1,308 litters of purebred Yorkshire and Landrace sows.

Result: In F_1 sows, heterosis was manifested in all traits with 6.7-6.4% for TNB; 5.4-6.2% for NBA; 4.4-4.8% for NW and 5.7-6.0% for AWW traits. Additionally, direct dominance was the most positive effect on litter traits in crossbred sows. In rotational crossbred sows of L (YL) and L (LY), while the value of litter traits remarkably decreased in comparison with F1 groups, it was a noticeably higher than that of the purebred sows by 1.4-3.0%. In un-tested crossbred groups of Y (YL) and Y (LY), predicted values for litter traits were equal in tested crossbred groups of L (YL) and L (LY) and lower than F_1 crossbred sows.

Key words: Crossbred sows, Dominance, Predicted values, Reproduction.

INTRODUCTION

Reproductive improvement of sows depends on suitable selection programs and crossbreeding strategy. Thanks to the heterosis, the diallel crossing system between Yorkshire and Landrace pigs is currently applied to increase reproductive efficiency of crossbred sows. However, to identify an efficient breeding scheme, crossbreeding parameters need to be estimated (Ibáñez-Escriche *et al.* 2014), especially for additive and dominant effects which are considered as the genetic basis of heterosis (Li *et al.* 2008). The genetic models based on direct and maternal additive and dominance effects were developed for generating crossbreeding parameters (Eisen *et al.* 1983). Moreover, these models were used as genetic tools to predict performance of un-tested crossbred groups in practical. In addition, combination effects generated by genetic differences among various breeds provides essential information to guide efficient use of genetic resources in pig crossbreeding systems (Cassady *et al.* 2002).

Effects of direct and maternal dominant genetic on growth, carcass quality traits in the crossbreeding system of Hampshire, Landrace and Large White have been documented (Baas *et al.* 1992; Bittante *et al.* 1993). However, these effects were only observed in crossbred terminal sires Duroc and Pietrain (Tinh *et al.* 2015), Pietrain and Landrace (Hop *et al.* 2015) and between Duroc and Landrace (Hào *et al.* 2015). Additionally, heterosis and combination effects on growth, carcass quality and reproduction in pig crossbreeding system were also reported in pig breeding scheme (Cassady, *et al.* 2002). Thus, this study is aimed at estimating the effects of direct additive and dominance on litter traits and predicting the reproduction of un-tested crossbred sows between Danish Yorkshire and Landrace pigs in Vietnam.

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MATERIALS AND METHODS

Materials

To estimate the crossbreeding effects, from 2014 and 2017, 1979 litters including 1,308 litters of purebred Danish Yorkshire and Landrace sows and 671 litters of crossbred sows, including YL (Yorkshire-Sire × Landrace-Dam), LY (Landrace-Sire × Yorkshire-Dam), L(YL) and L(LY) were obtained between in two pig breeding farms: Binh Thang and Khang Minh An. Three groups of un-tested crossbred sows were also included in analysis for predicting litter performance based on estimates of crossbreeding effects including Y (YL), Y (LY) and (YL)(LY). Analyzed traits in this study were total number born (TNB), number born alive

(NBA), number weaned (NW) and average piglet weight at weaning (AWW).

Statistical analysis

Heterosis in percentage was identified by formula:

$$\bar{H}\ (\%) = \frac{\bar{X}_F - \bar{X}_P}{\bar{X}_P} \times 100$$

Where,

$\bar{H}$ = Heterosis (%).

$\bar{X}_F$ = Average performance in progenies.

$\bar{X}_P$ = Average performance in parents.

Statistical analysis on phenotype of crossbred groups for litter traits was performed using SAS software (version 9.3.1) by GLM (General Linear Model) procedure and statistical model:

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Where,

Y_{ij} = Measurements of tested traits.

μ = Average value of observations.

α_i = Genetic group effect.

e_{ij} = Random error.

Crossbreeding effects (direct additive, direct dominance, maternal additive, maternal dominance) and predicted performance of un-tested crossbred groups were estimated using software CBE (Wolf, 1996) by Jakubec statistical model:

$$\bar{G} = \mu + Ad + Dd + Am + Dm + e$$

Where,

$\bar{G}$ = Average phenotype of crossbred groups.

μ = Average phenotype of crossbred groups.

Ad = Direct additive effect.

Dd = Direct dominant effect.

Am = Maternal additive effect.

Dm = Maternal dominant effect.

e = Random error.

RESULTS AND DISCUSSION

Litter performance and heterosis in crossbred sows

In inbreeding systems, increased proportion of homozygosity leads to inbreeding depression, particularly for traits related to reproduction, early growth and survival. However, the level of inbreeding in off spring will be diminished and traits of interest will be improved when two genetically different populations are crossed (McLaren, *et al.* 1987). The value of litter traits at birth and at weaning period was presented in Table 1 and Table 2, respectively. Our results showed that for all litter traits of TNB, NBA, NW and AWW, value differences between purebred and crossbred groups were statistically significant. In F1 crossbred sows' generation, heterosis effect was observed in all studied traits and insignificant difference was observed between YL and LY crossbred groups including 6.7-6.4% for TNB, 5.4-6.2% for NBA, 4.4-4.8% for NW and 5.7-6.0% for AWW traits. This indicated that there was not any remarkable distinction in selecting Yorkshire or Landrace as sire or dam when targeting for reproduction traits.

Previous studies indicated that in crossbred sows, the manifestation of heterosis effect can be observed on litter traits including litter size, litter weaning weight and pig survival (Lukač *et al.* 2012; McLaren *et al.* 1987). However, there was a noticeable difference between YL and LY groups in diallel crossing system for litter traits was reported (Dragomir 2013; Kantanamalakul *et al.* 2007). In this study, insignificant difference between YL and LY crossbred sows for litter traits could be explained by closer genetic structure of pure Danish Yorkshire and Landrace, which could be also one of the causes for moderate heterosis displayed in current study as compared with reported studies. Additionally, environment can be a have remarkable influences to the level of heterosis present in a crossbred population (Sheridan 1986). Therefore, genetic evaluation program and environmental improvement should be carried out simultaneously in these genetic studies under practical conditions of Vietnam.

As crossbred female individuals from F1 generation were used as dams to mate with pure parent for the next generation, the rotational crossbreeding system substantially reduces the proportion of pure line parental stocks. The level of heterosis in the crosses of rotational crossbreeding system was lower as compared to a terminal crossing system (Sheridan 1986). This phenomenon was also observed in this study. For crossbred sows of L(YL) and L(LY), a substantial decreasing trend was found for all studied litter traits as compared to F1 crossbred groups. However, the performance of these traits was slightly higher than that in purebred sows by 1.4-3.0% for these traits.

Table 1: Total number born (TNB) and number born alive (NBA) in crossbred sows between Danish Yorkshire (YY) and Landrace (LL) in Vietnam.

Genetic groups	Number litters	TNB (piglet)		NBA (piglet)	
		Mean±SE	H (%)	Mean±SE	H (%)
YY	497	14.06[b]±0.19		12.51[ab]±0.18	
LL	811	13.90[b]±0.18		12.49[b]±0.13	
YL	132	14.91[a]±0.31	6.7	13.18[a]±0.36	5.4
LY	295	14.88[a]±0.22	6.4	13.27[a]±0.23	6.2
L (YL)	143	14.18[b]±0.26	-1.4	12.96[ab]±0.37	0.9
L (LY)	101	14.27[b]±0.38	-0.7	12.76[b]±0.43	-0.9
P		0.02		0.049	

Where, P= Probability; H (%)= Heterosis in percentage.

Table 2: Number weaned (NW) and average piglet weight at weaning (AWW) in crossbred sows between Danish Yorkshire and Landrace in Vietnam.

Genetic groups	Number litters	NW (piglets)		AWW (kg/piglet)	
		Mean±SE	H (%)	Mean±SE	H (%)
YY	453	11.87^{b}±0.18		6.24^{b}±0.05	
LL	734	11.80^{b}±0.13		6.42^{ab}±0.04	
YL	104	12.36^{ab}±0.34	4.4	6.69^{a}±0.11	5.7
LY	253	12.40^{a}±0.24	4.8	6.71^{a}±0.07	6.0
L (YL)	143	12.19^{b}±0.35	0.9	6.45^{b}±0.10	-1.5
L (LY)	101	12.10^{b}±0.46	0.0	6.66^{a}±0.13	1.5
P		0.001		0.000	

Table 3: Estimates of crossbreeding effects on total number born (TNB), number born alive (NBA), number weaned (NW) and average piglet weight at weaning (AWW) in crossbred sows between Danish Yorkshire and Landrace in Vietnam.

Cross breeding effects	TNB (piglet)	NBA (piglet)	NW (piglet)	AWW (kg/piglet)
Parent's phenotype in average	13.98**	12.50**	11.84**	6.33**
Direct additive effect	0.09^{ns}	-0.04^{ns}	0.015^{ns}	-0.099^{ns}
Direct dominant effect	0.92**	0.73**	0.55*	0.37**
Maternal additive effect	-0.02^{ns}	0.05^{ns}	0.019^{ns}	0.001^{ns}
Maternal dominant effect	-0.18^{ns}	-0.005^{ns}	0.057^{ns}	0.0002^{ns}

Where, **: Significance with p<0.01; *: Significance with p<0.05; ns: No-significant (p>0.05).

Estimates of crossbreeding effects for litter traits in crossbred sows

In crossbreds, dominance effect and the combination of dominance effect and over-dominance effect are the main components influencing heterosis (Li *et al.* 2008). Over-dominance existence has also been observed for many traits in animal breeding programs based on genetic pleiotropism (Boysen *et al.* 2010; Dagnachew *et al.* 2011; Ishikawa 2009). In our study, over-dominance effect was not separately analyzed. The effect of direct dominance was the most to studied traits of crossbred sows YL and LY in relation to other effects, such as 0.92 piglets for TNB; 0.73 piglets for NBA; 0.55 piglets for NW and 0.37 kg for AWW (Table 3). However, thanks to the controlled inbreeding level in pure-breeding programs, heterosis in current crossbred population was at moderate level, even for low heritability traits as litter size, number born alive, number piglet and weight at weaning. In addition, the epistatic interaction, which could be more important as some genes linked closely together, was not investigated in this study (Abasht and Lamont 2007). Therefore, further studies on epistatic interaction will be needed for litter traits in Danish genetics of Y and L to improve the efficiency of breeding scheme.

Predicted litter performance of un-tested crossbred sows

Beside tested crossbred groups, we also predicted the value of TNB, NBA, NW and AWW traits in three un-tested groups based on estimated components of genetic effects from tested crossbred groups. The predicted phenotypes of litter traits in Y(YL), Y(LY) and (YL)(LY) sows were presented in Table 4 (at birth) and Table 5 (at weaning).

Table 4 showed that deviation between observed and estimated values in tested crossbred groups was remarkably low for TNB trait (0.00 to 0.06 piglets) and NBA trait (0.00 to -0.11 piglets). This indicated the high accuracy of predicted means for both TNB and NBA trait in un-tested crossbred groups. Predicted values for TNB and NBA trait in Y(YL), Y(LY) and (YL)(LY) were lower than that of F1 crossbred groups YL and LY, but equal to that of rotational crossbred groups L(YL) and L(LY). Similarly, for the NW and AWW traits, the accuracy of predicted values in un-tested crossbred groups was considerably high, which reflected in the low deviations between observed and estimated values, from 0.00 to -0.06 piglets for NW and from 0.00 to -0.12 kg for AWW. As a result, in un-tested crossbred groups of Y(YL), Y(LY) and (YL)(LY), predicted reproduction means were equal to rotational crossbred groups of L(YL) and L(LY), but lower than F1 crossbred groups of YL and LY.

Conclusively, our data in current research suggested that there was not any difference between Danish Y and L purebred as well as between LY and LY crossbred sows for studied traits (TNB, NBA, NW and AWW). This means using of purebred Y or L individuals as sire or as dam to produce crossbred sows in dialed crossing system did not affect to reproduction traits of F1 crossbred progenies under practical conditions in Vietnam. As for rotational crossbreeding system, such as, L (YL), Y(YL), L(LY) and L(YL), the proportion of Y or L purebred parent was reduced in progeny generation and lower heterosis for litter traits was observed as compared with F1 crossbred sows. It resulted in reproduction dropped down in rotational crossbred sows but was still higher than purebred parents for those traits. Therefore, as mentioned to biological performance, the diallel crossing system between Danish Yorkshire and Landrace to produce F1 crossbred sows should be recommended. But economically, the rotational crossing system among these purebreds should be considered to

Table 4: Prediction for total number born (TNB) and number born alive (NBA) in un-tested crossbred sows between Danish Yorkshire and Landrace in Vietnam.

Traits	Genetic groups	No. litters	Observed mean	Estimated mean	Deviation
TNB trait (piglets)	YY	497	14.06	14.06	0.00
	LL	811	13.90	13.90	0.00
	YL	132	14.91	14.91	0.00
	LY	295	14.88	14.88	0.00
	L(YL)	143	14.18	14.21	0.03
	L(LY)	101	14.27	14.21	-0.06
	Y(YL) (un-tested)			14.30±0.32	13.69-14.92*
	Y(LY) (un-tested)			14.30±0.32	13.69-14.92*
	(YL)(LY) (un-tested)			14.26±0.24	13.78-14.73*
NBA trait (piglets)	YY	497	12.51	12.51	0.00
	LL	811	12.49	12.49	0.00
	YL	132	13.18	13.18	0.00
	LY	295	13.27	13.27	0.00
	L(YL)	143	12.96	12.87	0.09
	L(LY)	101	12.76	12.87	-0.11
	Y(YL) (un-tested)			12.84±0.37	12.12-13.56*
	Y(LY) (un-tested)			12.84±0.37	12.12-13.56*
	(YL)(LY) (un-tested)			12.86±0.31	12.26-13.56*

(*): Confidence interval with α=0.05.

Table 5: Prediction for number weaned (NW) and average piglet weight at weaning (AWW) in un-tested crossbred sows between Danish Yorkshire and Landrace in Vietnam.

Traits	Genetic groups	No. litters	Observed mean	Estimated mean	Deviation
NW trait (piglet)	YY	453	11.87	11.87	0.00
	LL	734	11.80	11.80	0.00
	YL	104	12.36	12.36	0.00
	LY	253	12.40	12.40	0.00
	L(YL)	143	12.19	12.16	0.03
	L(LY)	101	12.10	12.16	-0.06
	Y(YL) (un-tested)			12.17±0.36	11.46-12.89*
	Y(LY) (un-tested)			12.17± 0.36	11.46-12.89*
	(YL)(LY) (un-tested)			12.16±0.30	11.57-12.76*
AWW trait (kg/piglets)	YY	453	6.24	6.24	0.00
	LL	734	6.42	6.42	0.00
	YL	104	6.69	6.69	0.00
	LY	253	6.71	6.71	0.00
	L(YL)	143	6.45	6.57	-0.12
	L(LY)	101	6.76	6.57	0.20
	Y(YL) (un-tested)			6.47±0.11	6.25-6.68*
	Y(LY) (un-tested)			6.47±0.11	6.25-6.68*
	(YL)(LY) (un-tested)			6.52±0.09	6.34-6.96*

apply for specific production conditions to continue using the advantage of crossbred dams.

CONCLUSION

Under practical in Vietnam, direct dominance component was the most positive effect on litter traits of total number born, number born alive, number weaned and average piglet weight at weaning in crossbred sows produced from Danish purebred Yorkshire and Landrace.

The manifestation of heterosis in F1 crossbred sows was at moderate level for studied litter traits, respectively; 6.7-6.4% for total number born; 5.4-6.2% for number born alive; 4.4-4.8% for number weaned and 5.7-6.0% for average piglet weight at weaning. As applying the rotational crossing system, reproduction dropped down as compared with F1 diallel crossbred sows, but was higher by 1.4-3% than purebred parents for litter traits.

Economically, the rotational crossing system among purebreds of Danish genetics of Yorkshire and Landrace should be considered to apply for specific production conditions to continue using the advantage of crossbred dams; and also a further study on epistatic interaction should be done for litter traits in to improve the efficiency of breeding scheme.

Ethics statement

Samples collected were used only for routine diagnostic purpose of the breeding programs and not specifically for the purpose of this project. Therefore, approval of an ethics committee was not mandatory. Sample collection and data recording were conducted strictly according to the Vietnamese law on animal protection and welfare.

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