Effect of genotype, sex and parity on growth traits of diallel crossed Nigerian indigenous and exotic pigs

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Abstract

Three breeds of pig namely; Indigenous (IN), Large white (LW) and Landrace (LR) breeds were crossed in full diallel arrangement to evaluate the effects of cross, sex and parity on growth traits as well as establish the nature of gene action due to the growth traits at birth, weaning and 20 weeks of age. Each line crossed in a full 3x3 diallel cross resulted in a total of 132, 107 and 105 pigs at birth, weaning and 20 weeks of age respectively. General Combining Ability (GCA), Specific Combining Ability (SCA) and Reciprocal Effects (RE) were estimated for eight traits which includes Body weight (BWT), Ear length (EL), Tail length (TL), Heart girth (HG), Snout circumference (SC), Snout length (SL), Height at wither (HW) and Body length (BL). There were significant differences ($P < 0.05$) among the various crosses, sex and parity but no significant interaction. The LRxLW cross consistently expressed higher body weight and morphometric traits than other crosses at birth, weaning and 20 weeks of age, while the INxIN expressed least body weight at birth and 20 weeks of age, while LWxIN was the least at weaning. There was no significant GCA effect ($P > 0.05$) on all the traits measured, but SCA was significant ($P < 0.01$) for all morphometric traits and body weight. RE was significant for body weight at birth and weaning, while at 20 weeks, was significant for SC and HW. The non-significant GCA estimates along with significant SCA estimates suggest that the genes governing the eight traits measured do not act additively, but non-additively, implying that improvement of those traits may be attained by exploiting heterosis through planned crossbreeding. However, the significant reciprocal effect in body weight and some morphometric traits indicates maternal and sex-linked effect at the affected ages, implying that significant reciprocal cross may be used to attain high performance for the growth traits in the progeny.

Key words: Diallel cross, General combining ability, Specific combining ability, Reciprocal effects, Indigenous pigs, Growth traits.

Introduction

Swine breeding and genetics has advanced tremendously utilizing crossbreeding techniques in order to exploit heterosis. Heterosis is the difference between crossbred animals and the average of their

purebred counterparts (Ibe, 1998). With general use of breed and strain crossing in current swine production, it is important to estimate basic parameter values with which to evaluate and identify superior crossing combinations. The results of most

crossbreeding work have in general shown an advantage in the performance of crosses over that of their parents; however, literature concerning the general and specific combining abilities of lines is not extensive. Combining ability, as used by animal and plant breeders, is divided into general and specific combining ability. General combining ability (GCA) is a measure of the average performance of a line in hybrid combination, while specific combining ability (SCA) refers to specific crosses that do better or worse than would be expected based on the average performance of the lines involved (Carmon, 1976). One of the studies that support the idea that breeds have different behaviour when used in crosses was presented by Schneider (1976), in studies involving Landrace and Poland China crosses. These results indicated that crossbred animals were superior to purebred animals in number of live piglets, vigour of offsprings at birth, survival from birth to weaning and litter weight at weaning.

Desirable characteristics of different breeds can be utilized if some breeds can be identified as good maternal breeds and others as good paternal breeds (Buchanan *et al.*, 2005). Okoro *et al.* (2012a) had earlier reported a significantly better performance of black turkey sire genotype in cross with white dam genotype as paternal breed than bronze genotype. The diallel cross is commonly used in plant and animal breeding in evaluating the genetic structure of a population of pure-bred lines. An accurate analysis of this mating design is therefore not only of theoretical but also of practical economic importance and has been dealt with by many authors (e.g. Eisen *et al.*, 1983; Virk *et al.*, 1985; Okoro *et al.*, 2012a). A common assumption underlying most analyses of the diallel cross is the absence of any reciprocal differences,

which are primarily caused by sex-linkage and maternal effects. Although the effects of such differences on the analysis of diallel crosses have been examined by Wearden (1964), Durrant (1965), Eisen *et al.* (1966), Topham (1966), and Mather and Jinks (1982), these investigators were primarily concerned with testing the significance of possible effects and with determining the probable cause of reciprocal effects. Although reciprocal cross is of crossbreeding fundamental, there is a dearth of information on the effect of GCA, SCA and reciprocal effects on crosses involving local pigs of the tropical rainforest region especially of South-Eastern Nigeria.

This experiment therefore, was conducted to investigate the effect of cross, parity, sex and their interactions on growth traits, as well as evaluate the additive and non-additive genetic effects on growth traits in crosses of Indigenous pigs of South-eastern Nigeria and their exotic counterparts.

Material and Methods

Study location

This research was carried out at the piggery unit of the Federal University of Technology Teaching and Research Farm. The mean annual rainfall is 2500mm, temperature ranges from 26.5 to 27.5° C, and humidity ranges from 70 to 80%. This research was conducted between March 2009 and September 2012.

Management of parent stock and experimental animals

The parent animals were fed concentrates containing 17% crude protein (CP) and 2,480 Kcal/kg energy. A compounded feed containing 24% CP and 2,500 Kcal/kg energy was also used to flush the sows before mating in order to increase the litter

size and provide enough nutrients for embryonic and foetal development. Prior to mating the animals, the barrows and gilts were placed in separate pens, until heat was detected in the gilts the second time because at first heat, they were not mated until the second detected heat. Females were taken to the boar according to the mating design culminating to two parities per cross for main and reciprocal crosses. For the inseminated groups (WAI x LW, WAI x LR, LR x WAI and LW x WAI), semen were harvested, processed using cheese cloths to separate the gelatinous fraction and inseminated using pig catheters within the same day of collection. After mating/insemination, the sows were removed from the pen to their individual pens. On confirmation of pregnancy, the in-gilts were kept in pairs until about 14 days to parturition; before been moved to farrowing pens until parturition occurs. At this time, quantity of their diet was increased up to 4.0 kg per sow feed with fresh clean water provided. After parturition, the live piglets were retained with their dams to suckle the colostrum while still birth and dead ones were later examined and parameters taken before they were buried. Wood shavings were provided as litter materials for insulation. The dams were given antibiotics of 2 mls volume in order to reduce bacterial load to the suckling piglets, while the piglets were given iron injection to prevent piglet anaemia two days after birth. Records on birth weight and morphometric traits were taken. Notching of the piglets, for identification was done seven days after parturition and weaning was done at nine weeks of age. Piglets were weaned and provided high-protein diet (starter ration) from four weeks post birth, while *ivomectin* was also administered to those with skin infections. At weaning, they were

dewormed before putting them in the grower pens. They were fed and measurements taken until maturity age of 20 weeks.

Mating design and data collection

A full diallel cross comprising three breeds (Nigerian Indigenous, Large white and Landrace) of pigs made up of 5 sires per breed and 10 dams per breed was conducted, and a total of 132 offsprings were generated at birth (Table 1). The method of identification was through the use of ear notching. Each individual (offspring) was identified based on the family ear notching area.

The animals were housed under intensive system of with dwarf walls and asbestors with all routine medications given at the appropriate time. The linear body measurements and body weight were taken on weekly basis. The parameters taken in linear body measurements include the Ear length (EL), Tail length (TL), Heart girth (HG), Snout circumference (SC), Snout length (SL), Height at wither (HW) and Body length (BL). The linear body measurements were taken using the measuring tape, while the live body weight (BWT) was measured using a weighing scale.

Statistical analysis

Data obtained was first subjected to analysis of variance, to test the null hypothesis that there were no significant differences among the crosses, sex, parity and their interactions. The GLM procedure of SAS (1999) was used to conduct the analysis of variance and where significant differences was established among the crosses, sex and parity, Student-Newman-Keuls multiple range test according to SAS (1999) was used to separate the means. The method of Griffing (1956), according to Siewerdt and Dionello (1991) was further

Table 1: Number of pigs produced by Sire and Dam lines at birth

Sire lines	Dam lines		
	IN	LW	LR
IN	10	9	11
LW	12	26	15
LR	11	14	24

used to examine the diallel cross using the statistical model for combining abilities:

$$Y_{ij} = \mu + g_i + g_j + s_{ij} + r_{ij} + \frac{1}{n_{ij}p^2} e_{ijk}$$

Where,

Y_{ij} = Mean of ij^{th} cross between line i (as sire) and line j (as dam)

μ = Overall mean

g_i/g_j = General combining ability (GCA) of the i^{th}/j^{th} breed

s_{ij} = Specific combining ability (SCA) of the ij^{th} combination

r_{ij} = Reciprocal effect (RE)

n_{ij} = Number of individuals produced from i^{th} and j^{th} parental cross

p = Number of strains used in the cross

e_{ijk} = Error associated with k^{th} individual observation from the i^{th} and j^{th} crosses.

The mean squares for GCA, SCA and RE were generated using the methods given by Siewerdt and Dionello, (1991) according to Okoro *et al.* (2012a). Values of GCA, SCA and RE were computed using the expressions given by Obasi and Ibe (2008).

Results and Discussion

Effect of genetic groups, sex and parity

The least square means and standard errors for the different crosses, sex and parity are presented in Tables 2, 3 and 4 at birth, weaning and 20 weeks of age respectively. There were significant differences between the various crosses, sexes and parity indicating that they exhibited different levels of performance in terms of body weight and morphometric traits. Among the crosses, LRxLW was significantly highest ($P < 0.05$) for bodyweight at birth, weaning and 20 weeks of age, although the cross LRxIN and LWxLW were not significantly different from LRxLW at

weaning. Apart from TL which was not significantly different between the crosses at 20 weeks of age, all the other morphometric traits showed significant difference ($P < 0.05$) at birth, weaning and 20 weeks of age. Females were heavier than males at birth and weaning, but no significant differences for the morph metric traits recorded at all the ages measured. This is not in line with the typical sexual dimorphism expressed in most avian and mammalian species according to Ikeobi *et al.* (2005). This could be ascribed to more females farrowed compared to males. Parity 2 was significantly higher than parity 1 for morphometric traits – HG and HW at birth, while parity 1 was significantly higher than parity 2 for EL and TL at weaning and EL only at 20 weeks of age. Previous work has demonstrated parity effects for numerous sow traits to increase as the number of parity increases. Baas *et al.* (1992) reported that the effects of parity on weaning weight increases initially and then decreases in subsequent parities. Similarly, the American National Swine Improvement Federation (1997) defined parity 4 as the parity in which sows peak most production traits before it declines.

Analysis of Variance for Diallel crosses

The analysis of variance tables for testing the significance of GCA, SCA and RE are summarized in Table 5. There was no significant GCA for BWT and all the morphometric traits measured at all the ages, implying the non importance of

Table 2: The least square means and standard errors for body weight and linear body measurements at Birth

Source ¹			Traits ²								
Sire	Dam	BWT	EL	TL	HG	SC	SL	HW	BL		
Lines	Lines	(g)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)		
Crosses	IN	IN	0.92±0.05 ^d	4.90±0.28 ^{bc}	7.50±0.17 ^a	23.40±0.22 ^{ab}	7.50±0.22 ^e	4.80±0.13 ^a	17.20±0.25 ^c	18.90±0.43 ^d	
		LR	1.37±0.07 ^c	4.36±0.20 ^c	3.82±0.50 ^{bc}	18.45±1.31 ^c	12.55±0.68 ^{cd}	3.18±0.12 ^{cd}	17.36±0.66 ^c	30.64±1.58 ^{bc}	
		LW	1.61±0.16 ^b	4.33±0.24 ^c	3.67±0.44 ^c	17.11±0.96 ^c	13.44±0.18 ^{bc}	3.44±0.18 ^{cd}	16.67±0.41 ^c	26.56±0.77 ^c	
	LR	IN	1.72±0.08 ^b	4.18±0.18 ^c	5.09±0.34 ^b	17.27±0.51 ^{ab}	11.18±0.60 ^d	3±0 ^d	17.18±0.33 ^c	35.18±0.58 ^a	
		LR	0.93±0.08 ^d	5.42±0.27 ^{ab}	6.63±0.31 ^a	23.75±1.71 ^{ab}	15.50±0.47 ^a	5.04±0.13 ^a	20.25±0.74 ^b	27.58±1.02 ^c	
		LW	2.10±0.09 ^a	4.50±0.19 ^d	4.50±0.52 ^{bc}	22.64±1.29 ^{ab}	14.79±0.50 ^{ab}	4.25±0.17 ^b	19.43±0.45 ^b	29.64±1.35 ^{bc}	
	LW	IN	1.09±0.04 ^d	3.25±0.13 ^d	4.08±0.39 ^{bc}	18.58±0.65 ^c	12.92±0.96 ^{cd}	3.75±0.13 ^{bc}	15.67±0.53 ^c	29.92±2.02 ^c	
		LR	1.67±0.12 ^b	4.67±0.13 ^{bc}	3.53±0.24 ^c	22.0±0.58 ^b	15.0±0.45 ^{ab}	3.47±0.13 ^{bc}	19.93±0.56 ^b	32.53±0.82 ^{ab}	
		LW	0.98±0.04 ^d	5.73±0.23 ^a	7.46±0.31 ^a	25.31±0.97 ^a	16.23±0.48 ^a	4.89±0.19 ^a	21.96±0.76 ^a	29.12±1.05 ^{bc}	
	Sex	SEX 1	Male	1.25±0.06 ^b	4.75±0.13	5.32±0.25	21.96±0.60	14.16±0.38	4.14±0.11	19.24±0.39	28.35±0.69
		SEX 2	Female	1.38±0.07 ^a	4.84±0.16	5.66±0.27	21.66±0.62 ^b	13.67±0.43	4.22±0.13	18.91±0.44 ^b	29.20±0.74
	Parity	Parity 1	parity 1	1.35±0.06	4.69±0.13	5.60±0.26	20.73±0.49 ^a	13.17±0.36	4.17±0.12	18.38±0.32 ^a	28.16±0.69
	Parity 2	parity 2	1.27±0.06	4.88±0.15	5.38±0.26	22.79±0.67 ^a	14.12±0.44	4.19±0.12	19.71±0.46 ^a	29.32±0.74	

^{abcd} means with different alphabets on the same column are significantly different (P<0.05).

¹ IN = Indigenous breed, LR = Landrace breed, LW = Large white

² BWT = Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

Table 3: The least square means and standard errors for body weight and linear body measurements at Weaning

Source ¹			Traits ²								
Sire	Dam	BWT	EL	TL	HG	SC	SL	HW	BL		
Lines	Lines	(g)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)		
Crosses	IN	IN	3.72±0.34 ^{bc}	6.44±0.50 ^b	7.33±0.76 ^{ab}	31.56±0.67 ^{bc}	11.22±0.36 ^d	7.33±0.41 ^a	28.56±0.96 ^c	32.44±1.53 ^d	
		LR	4.12±0.32 ^{bc}	8.50±0.27 ^a	6.20±0.25 ^{bc}	33.70±0.65 ^{bc}	24.10±0.61 ^a	7.20±0.13 ^{ab}	34.70±0.63 ^a	43.40±1.06 ^{bc}	
		LW	4.03±0.32 ^{bc}	7.0±0.29 ^b	6.11±0.20 ^{bc}	36.78±2.78 ^{abc}	18.22±0.62 ^c	5.89±0.26 ^c	31.22±2.20 ^{abc}	40.11±0.98 ^c	
	LR	IN	5.72±0.39 ^a	8.11±0.26 ^a	5.89±0.20 ^c	30.11±1.84 ^c	22.00±0.69 ^{ab}	6.44±0.29 ^b	28.78±1.53 ^{bc}	43.44±1.37 ^{bc}	
		LR	4.36±0.3 ^{bc}	8.80±0.35 ^a	8.30±0.22 ^a	36.40±1.12 ^{abc}	20.65±0.56 ^b	6.45±0.17 ^{bc}	32.75±1.05 ^{abc}	44.15±1.13 ^{abc}	
		LW	6.74±0.32 ^a	8.25±0.25 ^a	6.63±0.18 ^{bc}	40.63±1.25 ^a	22.38±0.82 ^{ab}	6.50±0.19 ^{bc}	34.88±0.81 ^a	49.13±2.02 ^a	
	LW	IN	2.94±0.15 ^c	8.29±0.18 ^a	6.29±0.29 ^{bc}	34.86±2.42 ^{abc}	18.71±0.42 ^b	6.0±0.31 ^c	31.71±2.42 ^{abc}	39.57±1.02 ^c	
		LR	4.51±0.25 ^b	8.54±0.22 ^a	6.23±0.23 ^{bc}	33.62±1.24 ^{bc}	21.00±0.69 ^b	5.77±0.23 ^c	29.46±0.98 ^{bc}	43.54±1.16 ^{bc}	
		LW	6.19±0.35 ^a	8.27±0.22 ^a	8.46±0.24 ^a	37.41±1.54 ^{ab}	22.10±0.61 ^{ab}	6.64±0.19 ^{ab}	33.96±1.05 ^{ab}	47.09±1.21 ^{ab}	
	Sex	SEX	Male	4.59±0.20 ^a	8.17±0.15 ^a	7.24±0.20 ^a	35.85±0.75 ^a	20.22±0.47 ^a	6.54±0.12 ^a	32.36±0.65 ^a	43.46±0.81 ^a
		1	Female	5.18±0.23 ^a	8.13±0.20 ^a	7.06±0.20 ^a	34.69±0.91 ^a	20.69±0.61 ^a	6.40±0.13 ^a	31.69±0.68 ^a	43.10±0.88 ^a
		SEX									
2											
Parity	Parity	parity	4.95±0.22 ^a	8.62±0.16 ^a	7.38±0.21 ^a	34.60±0.63 ^a	20.18±0.49 ^a	6.52±0.14 ^a	31.72±0.67 ^a	43.98±0.80 ^a	
	1	1	4.77±0.22 ^b	7.73±0.16 ^b	6.97±0.19 ^b	35.97±0.93 ^b	20.65±0.56 ^b	6.44±0.12 ^b	32.35±0.65 ^b	42.70±0.86 ^b	
	Parity	parity									
	2	2									

^{abcd} means with different alphabets on the same column are significantly different (P<0.05).

¹ IN = Indigenous breed, LR = Landrace breed, LW = Large white

² BWT = Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

additive genetic effects for all the phenotypes of these traits measured. Meanwhile SCA was significant (P<0.01) for BWT and morphometric traits measured at all the ages measured, indicating the importance of dominance. However, RE was significant (P<0.05) for BWT at birth and weaning, while at 20 weeks, it was significant (P<0.01) for SC and HW. In addition, SC and HW are influenced by maternal effects at 20 weeks of age as significant reciprocal effects are usually ascribed to maternal influence. This suggests a high maternal effect for BWT and morphometric traits measured at all the ages measured and the subsequent likelihood of sex-linkage due to the traits.

General Combining Ability

Estimates of GCA for all traits are shown in Tables 6, 7 and 8 for birth, weaning and 20 weeks of age respectively. The values of GCA for the IN genotype ranged from -2.05 for BL at 20 weeks to 0.81 for HG at weaning, while the LR genotype GCA ranged from 0.01 for TL at 20 weeks to 1.42 for BL at 20 weeks of age. The LW genotype GCA ranged from -0.01 for BWT and EL at 20 weeks to 1.17 for BL at birth. The LR genotype exhibited the highest GCA (0.082) for BWT followed by LW (0.018) and IN (-0.096) at birth. Also, at weaning and 20 weeks of age, LR breed exhibited the highest GCA (0.4 & 0.81) respectively. Apart from BWT trait, the LR

Table 4: The least square means and standard errors for body weight and linear body measurements at 20 weeks of age

Source ¹			Traits ²							
	Sire	Dam	BWT	EL	TL	HG	SC	SL	HW	BL
	Lines	Lines	(g)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
Crosses	IN	IN	8.24±0.60 ^c	8.22±0.57 ^c	8.56±0.82	42.56±0.93 ^c	15.56±0.24 ^d	8.56±0.34 ^a	36.78±0.98 ^c	49.0±0.82 ^c
		LR	28.58±1.25 ^{ab}	10.0±0.27 ^b	9.38±0.26	55.75±1.53 ^a	30.63±0.78 ^{ab}	9.88±0.13 ^a	61.13±2.11 ^a	66.38±2.60 ^a
		LW	21.88±0.99 ^d	9.44±0.18 ^b	9.11±0.26	53.33±2.31 ^{ab}	22.56±0.56 ^c	8.89±0.20 ^b	46.56±2.52 ^b	58.67±1.53 ^b
	LR	IN	24.79±1.82 ^{bcd}	9.56±0.18 ^b	8.89±0.26	47.22±2.60 ^{bc}	29.11±0.68 ^{ab}	9.78±0.15 ^a	43.11±1.57 ^a	68.78±2.25 ^a
		LR	22.83±1.06 ^{dc}	11.75±0.29 ^a	9.45±0.28	43.10±1.61 ^c	24.15±0.91 ^c	8.50±0.19 ^b	41.0±1.46 ^{bc}	56.95±0.66 ^b
		LW	30.58±0.67 ^a	9.75±0.16 ^b	9.38±0.18	52.75±1.25 ^{ab}	31.88±0.91 ^a	10.0±0.19 ^a	46.75±1.15 ^b	69.50±2.20 ^a
	LW	IN	26.57±2.83 ^{abcd}	10.29±0.29 ^b	8.86±0.14	45.71±3.21 ^c	21.43±0.69 ^b	8.57±0.29 ^{ab}	44.71±3.47 ^b	57.14±1.22 ^b
		LR	27.49±1.59 ^{abc}	9.54±0.18 ^b	8.85±0.15	44.85±1.56 ^c	27.85±1.02 ^b	9.15±0.29 ^{ab}	42.69±0.84 ^b	60.15±1.44 ^a
		LW	23.75±0.85 ^{bcd}	12.27±0.30 ^a	9.45±0.24	49.32±1.26 ^{bac}	27.91±0.86 ^b	9.36±0.12 ^{ab}	44.36±0.91 ^b	65.41±1.53 ^a
Sex	SEX	Male	23.29±0.89	10.58±0.22	9.25±0.14	48.11±0.99	25.44±0.69	9.04±0.13	44.67±0.99	60.91±1.01
	1	Female	24.22±1.02	10.44±0.25	9.08±0.18	47.17±1.03	26.33±0.79	9.25±0.12	44.15±1.11	61.73±1.81
	SEX									
Parity	2									
	Parity	parity 1	24.22±0.93	10.88±0.24 ^a	9.28±0.13	46.62±1.11	25.28±0.66	9.10±0.12	43.74±1.06	61.62±1.11
	1	parity 2	23.25±0.98	10.18±0.22 ^b	9.07±0.17	48.64±0.89	26.36±0.79	9.16±0.13	45.05±1.03	60.98±1.07
	Parity									
	2									

^{abcd} means with different alphabets on the same column are significantly different (P<0.05).

¹ IN = Indigenous breed, LR = Landrace breed, LW = Large white

² BWT = Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

genotype also exhibited the highest GCA in the morphometric traits - EL and SL at birth, weaning and 20 weeks of age. Previous study by Okoro *et al.* (2012a) reported non significant GCA effect for BWT and 5 morphometric traits at 12 weeks of age in a diallel cross involving locally adapted turkeys. However, Nestor *et al.* (2005) reported a significant additive genetic effect for BrWt, SL, walking ability and BWT at 8, 16 and 20 weeks of age in crosses of commercial turkeys. Berenskin and Hetzer (1986) reported a significant (P<0.1 to P<0.01) GCA effects for body weight at birth, 56 days and 140 days of age and non at 21 days of age for barrows in a diallel crosses involving High fat and Low fat lines

of swine, while non (P>0.05 to P>0.1) was recorded for the gilts.

Specific Combining Ability

SCA was significant (P<0.01) for all the traits measured (BWT and morphometric traits) at birth, weaning and 20 weeks of age. At birth, the cross LRxLW exhibited the highest SCA for all the traits measured except TL and BL while INxLW and INxLR had the least values except for INxLW which recorded the highest for TL and BL traits. At weaning, the LRxLW cross also reported the highest SCA for all the traits except SC and SL, while at 20 weeks, the LRxLW cross also reported the highest SCA for all the traits except EL, HG and SC traits where INxLR cross was higher. The

Table 5: Summary of the analysis of variance for the combining abilities at Birth, Weaning and 20 weeks of age.

1 Traits	2 Effects	BIRTH			WEANING			20 WEEKS		
		MS	99%	95%	MS	99%	95%	MS	99%	95%
BWT	GCA	0.049			0.795			3.852		
	SCA	8.198	**	*	54.830	**	*	2,108.056	**	*
	RE	0.387		*	5.805	**	*	30.56		
	Error	0.104			1.367			20.127		
EL	GCA	0.106			0.112			0.009		
	SCA	32.267	**	*	158.89	**	*	202.859	**	*
	RE	0.823			1.26			0.634		
	Error	0.869			1.006			1.125		
TL	GCA	0.06			0.025			0.004		
	SCA	11.45	**	*	67.0	**	*	190.795	**	*
	RE	1.82			0.19			0.387		
	Error	2.092			1.108			1.297		
HG	GCA	4.395			4.91			1.29		
	SCA	711.93	**	*	2,873.63	**	*	6,313.491	**	*
	RE	2.65			43.808			128.833		
	Error	15.69			30.548			38.584		
SC	GCA	1.54			3.691			13.77		
	SCA	431.04	**	*	1,189.443	**	*	2,081.195	**	*
	RE	1.454			4.363			13.197	**	
	Error	5.44			5.316			10.287		
SL	GCA	0.1			0.142			0.221		
	SCA	19.14	**	*	87.200	**	*	217.392	**	*
	RE	0.67			0.747			0.684		
	Error	0.41			0.683			0.571		
HW	GCA	2.155			0.0835			10.843		
	SCA	671.64	**	*	2,361.385	**	*	5,970.551	**	*
	RE	0.858			43.077			229.631	**	*
	Error	6.924			20.299			29.787		
BL	GCA	6.706			7.046			16.557		
	SCA	2480.24	**	*	4,574.757	**	*	10,299.14	**	*
	RE	19.432			21.007			63.63		
	Error	21.715			20.519			28.39		

¹ BWT = Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

² GCA = General Combining Ability, SCA = Specific combining ability, RE = Reciprocal effects.

MS = Mean squares, ** = P<0.01 (99%), * = P<0.05 (95%).

significant SCA is an indication of non-additive gene action for these traits which is thought to reflect dominance or epistatic gene action or both. This means that BWT and all the morphometric traits can be improved genetically through the appropriate crossing, utilizing heterosis. The results indicate that the LR genotype

performed generally well in crosses with the other exotic genotype – LW. Cross performance was poor for INxLW and INxLR suggesting less importance of non-additive gene action compared to LRxLW cross, although there was significant SCA effect. In some studies, it was suggested that non-additive genetic variations is an

important source of variation in growth traits, particularly in offspring of crosses of lines differing greatly in growth rate and body conformation (Bereskin and Hetzer, 1986). Bereskin and Hetzer (1986) reported a significant SCA effect at 21 days, 56 days and age in days at 79.4kg (AGE) for gilts in a diallel crosses involving High fat and Low

fat lines of swine, while no significance was attained with barrows. Emmerson *et al.* (1991) observed significant heterosis for BWT at older ages and shank length in F_1 reciprocal crosses of an experimental line selected long term for increased 16-week body weight and an older commercial sire line in turkeys. However, Eisen *et al.*

Table 6: Estimates of General Combining ability, Specific Combining ability and reciprocal effects of growth traits of crosses of pigs at birth

Parameters	Traits ¹							
	BWT (g)	EL (cm)	TL (cm)	HG (cm)	SC (cm)	SL (cm)	HW (cm)	BL (cm)
GCA _{IN}	-0.096	-0.12	0.034	-0.99	-0.527	-0.11	-0.657	-0.28
GCA _{LR}	0.082	0.14	0.081	0.503	0.045	0.14	0.15	-0.89
GCA _{LW}	0.018	-0.018	-0.113	0.50	0.482	-0.02	0.513	1.17
SCA _{INxLW}	0.45**	1.26**	1.29**	5.95**	4.393**	1.20**	5.383**	8.91**
SCA _{INxLR}	0.514**	1.424**	1.49**	5.85**	3.956**	-1.09**	5.76**	10.97**
SCA _{LRxLW}	0.628**	1.528**	1.34**	7.44**	4.964**	1.28**	6.56**	10.36**
RE _{INxLW}	0.261*	0.54	-0.21	-0.735	0.523	-0.16	0.50	-0.19
RE _{INxLR}	-0.172*	0.092	-0.64	0.59	0.684	0.09	0.09	-2.27
RE _{LRxLW}	0.217*	-0.084	0.49	0.32	-0.107	0.39	-0.25	-1.45

**=P<0.01, *=P<0.05 for H₀: parameters = 0

¹ BWT = Day 1 Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

Table 7: Estimates of General Combining ability, Specific Combining ability and reciprocal effects of growth traits of crosses of pigs at weaning

Parameters	Traits ¹							
	BWT (g)	EL (cm)	TL (cm)	HG (cm)	SC (cm)	SL (cm)	HW (cm)	BL (cm)
GCA _{IN}	-0.32	-0.093	-0.07	0.81	-0.21	0.06	-0.13	-1.05
GCA _{LR}	0.40	0.16	0.01	-0.29	0.87	0.12	0.11	1.12
GCA _{LW}	-0.08	-0.06	0.06	1.01	-0.66	-0.17	-0.98	-0.08
SCA _{INxLW}	1.16**	2.55**	2.07**	11.94**	6.16**	1.98**	10.49**	13.28**
SCA _{INxLR}	1.64**	2.77**	2.02**	10.64**	7.68**	2.27**	10.58**	14.47**
SCA _{LRxLW}	1.90**	2.80**	2.17**	12.37**	7.23**	2.05**	10.72**	15.44**
RE _{INxLW}	0.55**	0.643	-0.09	0.96	-0.25	-0.06	-0.25	0.27
RE _{INxLR}	-0.80**	0.19	0.16	1.79	1.05	0.38	2.96	-0.02
RE _{LRxLW}	1.11**	-0.14	0.20	3.51	0.69	0.37	2.71	2.79

**=P<0.01, *=P<0.05 for H₀: parameters = 0

¹ BWT = 8-weeks Body weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

(1983) suggested that data used to provide genetic interpretation of dominance effects can be further clarified by employing a re-parameterized model that provides joint estimates of heterosis and combining ability as opposed to specific heterosis and SCA. *Reciprocal Effect*

There were significant RE ($P < 0.05$ to $P < 0.01$) in BWT at birth and weaning, as well as for morphometric traits - HW and SC ($P < 0.01$) at 20 weeks of age. These implied that there were sex-linked or maternal effects exhibited by the various crosses for the traits BWT, HW and SC at the identified ages. Nestor *et al.* (2005) reported a significant RE for SL in male and female turkeys in a commercial sire line and a line selected for long term increased 16-week body weight using orthogonal contrasts. However, Silva *et al.* (1996), using Griffing's (1956) method, estimated the maternal and reciprocal effects on

bodyweight at birth, 21, 35, and 77 days in crosses involving Duroc, Landrace, Yorkshire and Large White and reported a significant maternal effect at birth, 21 days and 35 days of age and no significant reciprocal effect at these ages. Iraqi *et al.* (2007) reported significant reciprocal, maternal and sex-linked effects on growth traits of crosses involving four breeds of chicken. Ibe *et al.* (2005) also reported no significant reciprocal effects on bodyweight and linear body measurements in rabbits.

Conclusion

The lack of significant GCA implied that there were very small differences in the effects of additive genes for BWT, EL, TL, HG, SC, SL, HW and BL between the Indigenous, Large white and Landrace genotypes of pigs. Maternal and sex-linked effects can explain differences in the

Table 8: Estimates of General Combining ability, Specific Combining ability and reciprocal effects growth traits of crosses of pigs at 20 weeks of age.

Parameters	Traits ¹							
	BWT (g)	EL (cm)	TL (cm)	HG (cm)	SC (cm)	SL (cm)	HW (cm)	BL (cm)
GCA _{IN}	-0.79	0.04	-0.05	0.38	-0.87	0.76	-1.11	-2.05
GCA _{LR}	0.81	-0.03	-0.01	0.14	1.75	1.02	0.12	1.42
GCA _{LW}	-0.01	-0.01	-0.06	-0.57	-0.88	-0.57	-0.36	-0.38
SCA _{INxLW}	8.08**	3.29**	2.99**	16.51**	7.33**	1.66**	11.59**	15.22**
SCA _{INxLR}	8.92**	3.26**	3.04**	17.16**	9.96**	1.98**	9.37**	13.71**
SCA _{LRxLW}	9.68**	3.22**	3.04**	16.27**	9.95**	2.11**	14.76**	16.23**
RE _{INxLW}	-2.34	-0.42	0.13	3.81	0.56**	-0.19	-0.75**	0.54
RE _{INxLR}	1.89	0.22	0.24	4.26	0.76**	-0.46	3.76**	-0.32
RE _{LRxLW}	1.55	0.11	0.26	3.95	2.01**	0.55	1.91**	2.82

**= $P < 0.01$, *= $P < 0.05$ for H_0 : parameters = 0

¹ BWT = 20-week Birth weight, EL=Ear length, TL = Tail length, HG = Heart girth, SC = Snout Circumference, SL = Snout length, HW = Height at withers, BL = Body length.

observed phenotype for BWT, HW and SC of the progenies at birth, weaning and 20 weeks of age due to significant RE effects. The significant SCA for all the traits measured points to the importance of non-additive gene action for these traits; hence, improvement in these traits can be done by planned crossbreeding in order to exploit the existing heterosis.

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