Research Journal of Animal Sciences 1 (4): 139-145, 2007
ISSN: 1993-5269

Utilization of Nigerian Native Pig in Breeding 1. A Genetic Assessment of Crossbred Heterosis in Growth and Litter Size

P.E. Nwakpu and P.N. Onu
Department of Animal Production and Fisheries Management, Ebonyi State University,
P.M.B 053, Abakaliki, Ebonyi State, Nigeria

Abstract: The Nigerian native pig and 2 exotic breeds-Landrace and Large White were compared with their F_1 and F_1 by parental breed backcross populations for a range of growth and litter size traits to 40 weeks of age. Experimental pigs were raised intensively in a standard piggery pens during growth. The results showed outward demonstration of significant superiority by the exotic parental group, the F_1 group and the F_1×exotic backcross (Mainbackcross group) over and above that of the natives, the F_1×native backcrosses (reciprocal backcross group) in most of the characters monitored especially that of growth and litter size. An analysis of the genetic basis for heterosis of growth and litter size indicated that the native by exotic 2-loci parental epistasis was responsible for the low residual heterosis observed among the backcross genotypes. Litter size heterosis was low and negative among the crossbred populations. Based on the genetic parameters estimated, hybrid vigour in all generations subsequent to F_1 can be stepped up satisfactorily by adopting the Back and Criss-Cross heterosis Evaluation strategy (BAC-CET) being proposed.

Key words: Evaluation heterosis growth, litter size inbred native and exotic pig

INTRODUCTION

The contribution of livestock production to global food security is generally undervalued, particularly in developed country communities. Sansoucy *et al*. (1995) provided a review of contributions of livestock in achieving sustainable production systems. They also suggested that as human needs for food and agriculture products double over the coming decades, global food production from animal products will increase more rapidly than from plants in most developing countries with increasing purchasing power.

Over this same period and beyond, the large regional differences in human needs for food and agriculture and in production capacity will persist at the global level with almost 75% of world agriculture remaining at the low-to-medium-input levels.

Indigenous livestock breeds often possess valuable traits such as disease resistance, high fertility, good maternal qualities, unique product qualities, longevity and adaptation to harsh conditions and poor quality feed. These are all desirable qualities for achieving sustainable agriculture, under low-input conditions.

Integrating the indigenous strain of pig into the target gene pool in an organized pig breeding project will be beneficial for two reasons: Firstly, Williamson and Payne (1990) had noted that, the native pigs exhibit appreciable heterosis and nicking when crossed with their exotic counterparts. Secondly, the Nigerian native pig possesses high resistance and tolerance to major diseases and nutritional stress. A combination of the native strain with the exotic breeds will help to expand the already existing genetic basis needed for successful selective breeding in Nigeria.

By crossing the Nigerian native pig with the exotic breeds already existing in the country, several crossbreed populations of different genetic merit will be obtained. The situation already exists whereby restriction is being placed on importation of livestock breeds into the country. Consequently, breeders will have no option but to work with crossbred pigs. They will also have to select from within a local by exotic crossbred population that possessed considerable heterosis in its F_1 for obvious reasons. For instance, by continuous selection on existing exotic lines, time will come when at least one of the exotic parental lines used to produce the commercial lines has plateaued and alternative line of the same strain of breed will not be available and cannot be replaced.

This study reports a pre-selection evaluation of crossbred pigs generated from the matings between the Nigerian native pig and the exotic breeds of Large white and Landrace pigs. The study was necessitated by the

---

Corresponding Author: P.E. Nwakpu, Department of Animal Production and Fisheries Management, Ebonyi State University, P.M.B 053, Abakaliki, Ebonyi State, Nigeria

need to have information on the levels of heterosis in the F_1 and that of the residual heterotic performance by the backcross generations before starting a meaningful selection for a heterotic trait on a crossbred population. The data so obtained will further yield information on the mode of action of genes controlling the heterotic traits, without which any selection on such population could be misguided.

MATERIALS AND METHODS

The experiment was begun in 1997 and it involved the Nigerian native pigs and the Landrace and Large white breeds which were established.

Crossbreeding procedure: At eight and a half months of age, six boars and 18 sows from each exotic breed/strain (Large white and Landrace) were reciprocally mated to three boars and nine sows from the native group (Local) to generate F_1 crossbred populations with a total of 216 piglets. The mating arrangement which is part of the BAC-CET breeding design (Omeje, 1989) is shown in Fig. 1. Similarly, at eight and a half months of age, 15 sows from each crossbred group were backcrossed to their male parents to obtain 8 backcross progeny groups as illustrated in Fig. 1. Mating was at random on floor pens with a mating ratio of 1 boar to 3 sows or gilts. A total of 296 backcross piglets were produced.

Parental and F_1 populations: The Landrace, Large white (P_0) exotic and native Pig (P_0) base populations comprising 6 sows and 2 boars per group were established at the same time in November, 1997 at the Pig Breeding and Research Unit of Ebonyi State University, Abakaliki. The indigenous (native) pigs were sourced from Nsukka and Ikwo LGA while the exotic Landrace and Large White were procured from National Veterinary Research Institute (NVRI), Vom, Plateau State.

Generation	Genotype (Strain I)	Genotype (Strain II)		Genotype (Strain III)
P_0 (inbred)	LR×LR 1	N×N 2		LW×LW 3
F_1 (crossbred)	1×2 4	2×1 5	3×2 6	2×3 7
B_x (backcross)	2×5 8	1×4 9	2×7 10	2×6 11

P_0 = Base population LR = Landrace, LW = Large White
N = Native strain; F_1 = First filial generation (crossbreds),
B_x = Backcross (second filial generation)
Adapted from Omeje and Nwosu (1986).

Fig. 1: The crossbreeding strategy (BAC-CET) adopted for the determination of heterosis in pigs

The base population pigs were raised on standard breeding and feeding pens measuring 10.5×3.5 and 7.5×2.5 m^2, respectively. Inbred progeny generations were obtained for each of the three strains using within-strain mating. The within-strain mating was adopted to help purify the strains and to further achieve uniform genotypes with more stable gene frequencies before embarking on crossbreeding.

The base populations were raised under standard feeding and management procedures already described by Nwakpu and Omeje (2002) and crossed at maturity to produce F_1 parental and cross bred progeny pigs which were brooded and reared in the same manner as their parents.

Backcross populations: This generation was obtained by backcrossing of the F_1 crossbred sows in each group to the boars of the parental group. Artificial insemination and/or hand mating methods were employed in all the mating groups using a mating ratio of one boar to three sows. They were brooded and reared to 40 weeks of age at which, animals would have matured for breeding.

Feeding and medication: All piglets received water and feed ad libitum during the brooding and rearing to weaning periods. From weaning periods, piglets were fed rations containing 3000 kcal kg^{-1} ME and 22.0% CP, from growing to breeding/finishing, they received a growing diet containing 2800 kcal kg^{-1} ME and 17.0% CP. Deworming was done at appropriate periods as a matter of routine and parasites treated accordingly.

Measurements: Body weights of the individual pigs were measured using an 'AVERY' weighing scale at a bi-weekly intervals starting from birth to determine their weight gains to 40 weeks of age. Measured quantities offered were served each time to the pigs while left over feeds were also measured to determine feed intake of the pigs. Litter Size at Birth (LSB) and Litter Size at Weaning (LSW) was determined for each breeding groups (Fig. 1).

Table 1: Comparison of percentage heterosis expected under various mating schemes for dominance and parental epistasis model with complementary loci

Mating schemes	D hypothesis[a]	P (2-loci)[b]	E (3-loci)[c]
Purebred	0.0	0.0	0.0
F_1	100.0	100.0	100.0
F_2 (or two breed synthetic)	50.0	12.50	15.6
Backcross	50.0	25.0	12.5
Three way cross	100.0	50.0	25.0
Four ways cross	100.0	0.0	-50.0
Rotational cross (2 breeds)	66.7	44.4	29.6
Rotational cross (3 breeds	85.7	40.8	21.0

Percentage value are relative to F (Sheridan, 1981)

Statistical methods: Data from live weight of the various genotypes were subjected to ANOVA in a Completely Randomized Design (CRD), while data on feed intake, weight gain and feed efficiency parameters were subjected to a Randomized Complete Block Design (RCBD) (Snedecor and Cochran, 1967) to separate variation due to age.

In all cases, the multiple range test by Duncan (1955) was used to identify significantly different genotypes. The significance of heterotic effects was tested by means of the t-test.

Genetic analysis of heterosis: The complete dominance and parental epistasis model.

The heterosis obtained per group in the secondary crossbred generation was compared with F_1 figures following a model by Sheridan (1981). The strategy of the model is based on calculated contributions made by various mating schemes to non-additive effects (Table 1). In this model, the F_1 heterosis relative to itself is 100% whether it is complete dominance or epistatic gene action that is operating. The relative predicated value in this model then, it will be taken that the experimental data fitted well with the particular model of gene action responsible for heterosis.

RESULTS

Growth paremeters

Liveweight: The 4 population showed differences at birth to weaning which stem mainly from the maternal influences. However, differences between the secondary crossbred groups were not significant compared to that between the parental groups. With the disappearance of maternal effect by weaning period of 8 weeks of age, marked genotype differences were obtained in favour of the exotic strains, F_1 and the main backcrosses which were superior to other groups up to 40th week of age (Table 2).

Feed intake (kg feed pig^{-1}): Age dependent increase in feed consumed per pig was established by all the genotypes with varying magnitudes of intake at each period of growth to 40 weeks of growth. The overall intake per pig was lowest for the native percent and F_1×native backcross (reciprocal) which ate 1.50 kg and 2.5 kg per pig per day, respectively. The biggest feed was consumed by the exotic groups (3.5 kg/pig/day) followed by the main backcross (3.0 kg/pig/day), which differed significantly, ($p<0.05$)

Weight gain: The bi-weekly daily gains in body-weight varied considerably among the populations. The slowest rate of gain was recorded among the reciprocal backcross pigs with a 40-week average of 330 g pig^{-1} day whereas the fastest was 860/pig/day from the main backcross followed by 820/pig/day from the crossbred with the other genotypes in between.

Feed: Gain ratio: All groups had a general deterioration in feed: gain efficiency due to age. In the pre-weaning period of 0-8 weeks the crossbred groups appeared to have a higher efficiency compared to the parental and inbred groups. However, this was reversed as from weaning to 40 weeks.

Table 2: Descriptive statistics for body weight heterosis of the F_1 crosses between inbred exotics and native pigs, at different age periods

Age (weeks)	Statistics	LW×N^a	N×LW^b	CB^c	LR×N^d	N×LR^e	CB^f
0	Midparent P	1.25	1.25	1.25	2.43	2.43	2.43
	Dev. from P	0.22	0.48	0.35	0.25	0.18	0.21
	S.E	0.06	0.16	0.11	0.05	0.06	0.05
	% Heterosis	3.30*	2.50^{ns}	2.90	5.34	3.00	4.17
8	Midparent P	10.38	10.38	10.38	12.28	12.28	12.28
	Dev. from P	-2.12	1.28	-1.70	0.88	0.65	0.76
	S.E	0.47	0.39	0.40	0.36	0.23	0.20
	% Heterosis	-6.84	2.93^{ns}	-4.88	2.31	2.50	2.40
16	Midparent P	17.78	17.78	17.78	30.35	30.35	30.35
	Dev. from P	0.72	6.55	3.63	7.03	8.52	7.77
	S.E	0.29	0.89	0.50	0.23	0.16	0.17
	% Heterosis	2.26^{ns}	5.94	4.00	16.67	32.24**	24.45**
24	Midparent P	32.33	32.33	32.33	33.77	33.77	33.77
	Dev. from P	-1.33	10.00	5.66	3.90	16.23	10.06
	S.E	0.46	1.42	1.80	0.10	1.14	0.60
	% Heterosis	-2.85^{ns}	7.12	-4.98	28.90	16.96**	22.93**
32	Midparent P	48.17	48.17	48.17	51.50	5.50	51.50
	Dev. from P	7.50	13.50	-10.50	3.50	12.83	8.16
	S.E	0.58	3.06	1.80	0.76	0.11	0.50
	% Heterosis	-12.98	4.40	-8.69	4.25	19.80	27.02
40	Midparent P	64.33	64.33	64.33	67.17	67.17	67.17
	Dev. from P	-10.33	13.67	-12.00	4.83	17.83	9.83
	S.E	1.20	3.94	2.50	1.34	0.66	1.00
	% Heterosis	-10.66	3.29	-6.97	3.35	17.42**	10.38*

*$p<0.05$, **$p<0.01$ CB: Combined cross

Table 3: Litter Size at Birth (LSB) and Weaning (LSW) in crosses involving native and two exotic inbred crosses

Genotypes	Litter Size at Birth (LSB)	Litter Size at Weaning (LSW)
Po (Base Population)		
Strain I (LW)	8.20±0.50^{b}	7.70±0.40^{c}
Strain II (LR)	8.30±1.01^{b}	6.80±0.10^{b}
Strain III (N)	5.30±0.30^{a}	3/60±0.00^{a}
Inbred		
LW×LW	5.50±0.50^{a}	3.00±0.00^{a}
LR×LR	7.50±0.50^{b}	5.50±0.50^{b}
N×N	8.00±1.00^{b}	5.50±0.50^{b}
FI (Crossbred)		
LR×N	10.00±1.00^{C}	5.50±0.50^{a}
N×LR	8.00±1.00^{b}	7.50±1.50^{b}
LW×N	6.00±1.00^{a}	5.00±0.00^{a}
N×LW	6.50±0.50^{a}	4.00±1.00^{a}
Backcrosses		
(LR×N)×LR	8.50±0.50^{C}	4.50±0.50^{a}
(N×LR)×N	6.50±1.50^{a}	4.00±1.00^{a}
(LW×W)×LW	7.50±0.50^{b}	7.50±0.50^{C}
(N×LW)×N	6.00±1.00^{a}	6.00±1.00^{b}

a, b, c: Means on a row within a column not followed by same superscripts are different ($p<0.05$)

Table 4: Means and standard errors (kg) for heterosis in body weight of the backcross progeny groups

	Strains									
	(LR×N)×LR			(N×LR)×N			(LW×N)×LW			(N×LW)×N
Age (weeks)	F$_1$	EBX$_1$	MBX$_1$	EBX$_1$	RBX$_1$	F$_1$	EBX$_1$	MBX$_1$	EBX$_1$	RBX$_1$
0	1.42	1.46	1.52	1.38	2.00*	1.25	1.21	1.57*	1.26	0.97
	(0.02)	(0.07)		0.00	(0.1)		(0.03)		(0.03)	
8	12.28	13.26		11.3	5.33*		10.41		10.36	
	(0.52)	(0.39)	8.50**	(0.19)	(0.82)	10.38	(0.03)	9.07	(0.07)	4.87*
16	20.35	22.03		16.68	15.67		18.18		17.39	
	(0.59)	(0.67)	17.67*	(0.33)	(0.69)	17.78	(0.33)	19.33*	(0.00)	14.00
24	33.77	36.15		31.38	28.67		34.00		30.67	
	(0.39)	(0.88)	27.33**	(0.67)	(0.12)	32.33	(0.33)	29.67**	(0.67)	27.33*
32	51.50	54.25		48.75	4.00**		49.08		47.08	
	(0.76)	(1.20)	36.67**	(0.00)	(0.33)	48.17	(0.88)	41.67**	(0.67)	40.33**
40	67.17	70.58		63.75	52.67**		66.33		62.33	
	(1.33)	(1.00)	47.00**	(0.33)	(0.33)	64.33	(0.00)	60.00	(0.58)	52.00**

(*$p<0.05$ **$p<0.01$) (Standard errors are in parenthesis), EBX: Estimated Backcross, MBX: Main Backcross, RBX: Reciprocal Backcross

Litter size: Litter size at birth and weaning were significantly ($p<0.5$) different among the various genotypes. Litter size of 5.3 was the poorest from the native strain at the parental level but rose to 8.0 per litter at inbred level. The F$_1$ (crossbred) litter size of 10.0 and 8.0 were the best from the main and reciprocal crosses involving the landrace and native as against 6.0 and 6.5 involving large white and native.

Litter size at birth of 8.5 was best for the main backcross involving Landrace and worst 4.5 at weaning. Litter size of 7.5 piglets at weaning was the highest obtained from the main backcross of Large white and native (Table 3).

HETEROSIS IN BODY WEIGHT AND LITTER SIZE

Body weight heterosis: The heterotic performance of the weaned pigs to 40th weeks of age was much affected by genotypic differences (Table 4). The superiority of the F$_1$ in exhibiting hybrid vigour in this trait has been shown. In the 40th week, both the main and reciprocal back cross involving Large white and native had achieved 52 and 60% heterosis whereas the Landrace and native showed heterotic performance of 47 and 52.67%, respectively. It is obvious how the maincross involving the Landrace and native went down with advancing age to below the mid-parent. By the 40th week of age, the backcrosses were inferior to the mid-parent performance.

The litter size at birth: The litter size at birth recorded very low (negative) heterosis among the two exotic breeds and also a low and positive heterosis among the native strain. The lowest heterosis of (-8.54%) in the Litter Size at Birth (LSB) was achieved from the Large white breed which was significantly ($p<0.05$) different from the Landrace breed that recorded (-3.61) and (+3.77%) from the native strain, respectively that appeared to be the best.

Similarly, Litter Size at Weaning (LSW) was also very low and negative (-28.57%) from Large white breed and this was significantly different ($p<0.05$) from (-19.12%) from landrace and (-16.67%) from native strain.

DISCUSSION

Contrary to the expectation under the complete dominance hypothesis by Crow (1952) and many others that, the backcross generations should fall 50% behind the F_1, since heterosis was proportional to the degree of heterozygosity; results presented in Table 4 on the body size of the pigs behaved rather differently.

The magnitude of F_1 heterosis was more in the main crossbreds LWXN and LRXN during the preweaning age (Table 2) probably because, the main crossbred piglets benefited immensely from the superior and dominant exotic boars.

This impressive performance by the main-crossbred groups however, declined negatively after preweaning age because of the recessive maternal impact. Nevertheless, the reciprocal crossbreds rose from a non-significant heterotic effect to a maximum heterosis at the 16th week and thereafter declined gradually as the pigs attained maturity by the 40th week of age. The performance could be attributed to the expression of dominant growth alleles from the exotic dams, which manifested before the expression of recessive factor from the native Sires thereby dragging them back.

Generally, most of the crossbred groups presented different trends in their heterotic performance; Better heterosis were obtained from crossbreds involving Landrace and native. This implies that, the heterosis shown by these crosses were specific for each cross and depended on the differences in gene frequencies between parental lines (Falconer, 1989).

The heterosis expressed by the reciprocal back-crosses and that of the main backcrosses may have been influenced by the maternal environment or sex-linked. The main backcrosses were better in heterotic performances than the reciprocal backcrosses. The Main Backcrosses (MBX) had the advantage of higher additive merit E(BX) and higher deviations (heterosis) than the reciprocal backcrosses.

The higher additive merit of this group was contributed by the relatively larger body size of the exotic dams. The reciprocal backcrosses had lower heterotic deviations compared to the main backcrosses, because the smaller body size of the native dams constrained the F_1 crossbred gilts. It goes to imply that, both the main and reciprocal backcrosses were influenced by the type of female parents used at the backcross level. The tendency of the reciprocal backcrosses to incline towards the mid-point value and attain negative heterosis (Table 5) had been reported by Omeje (1985). He attributed this to the preponderance of native recessive (or null) genes in the backcrosses which overwhelmed the impact of the exotic genes in the group thereby bringing down the performance below mid-parent value.

The result as presented in Table 6 tends to fit perfectly with the 2-loci parental epitasis model demonstrated by Sheridan (1981). It further agrees with the observation by Wright (1977) and a host of other recent workers that inter-allelic gene interactions also interfere with the inheritance of many quantitative characters. For a much complex trait such as growth, therefore, it would seem inaccurate to predict the performance of backcross and subsequent generations from that of the F_1. The level of accuracy will further be reduced when 2 parental lines such as the small sized, low producing native pig and the large sized, improved Landrace and Large white breeds are crossed.

Table 5: Heterosis in bodyweight of the backcross progeny groups expressed as percentage of the F_1

Age (weeks)	F_1[a]	(LR×N)×LR[b]	(N×LR)×N[c]	(LW×N)×LW[d]	(N×LW)×N[e]
0	100	56.18	229.67	136.36	-77.60
8	100	-588.74	379.20	-32.60	-176.79
16	100	-30.77	15.04	-320.08	-16.95
24	100	-44.88	20.81	-361.75	60.67
32	100	-517.18	32.13	-78.17	176.36
40	100	-4140.60	68.08	-35.55	261.70

Table 6: Summary of the Backcross heterosis expressed as a percentage of the F_1[a] to ascertain modes of gene action in body weight

		Complete dominance		Parental (2 loci)	
Types of cross	Types of heterosis	Observed	Expected	Observed	Expected
HF_1 Crosses (combined)[b]		100.00	100.00	100.00	100.00
Backcrosses(BX)					
(LR×N)×LR[f]	$HMBX_1$[c]			23.12	
(N×LR)×N[g]	$HRBX_1$[d]			24.06	(25)
(Combined)	HBX[e]		(50)	23.59	
(LW×N)×LW[h]	$HMBX_1$			26.89	
(N×LW)×N	$HRBX_1$			23.25	(25)
Combined	HBX		(50)	25.07	

Sheridan (1981)

Litter Size at Birth (LSB) and at Weaning (LSW) involving Landrace and native pigs were significantly higher (Table 3) than that involving Large white and native. Sellier (1976) had earlier pointed out that crossbred females have more piglets per litter at birth and at weaning than purebreds and maintained that litter heterosis lead to slightly larger litter size at birth (+ 0.24 piglets per litter) and to higher piglet survival (+5.8%) and litter weights.

Reproductive traits have been described in literature as low in heritability and therefore show high heterosis. However, the negative heteroses observed among the crosses agrees with the report of Ghahabra *et al.* (1993). These authors attributed the low and negative heteroses to greater susceptibility of the parents to environmental conditions especially during farrowing and early maturity pregnancies of the parents. This indicates that, further crossings will neutralize this negative heteroses. Omeje (1985) had described negative heterosis as useful in future crossings especially as greater levels of heterosis are expressed in the females. Faster progress could be made by crossing to exploit heterosis.

CONCLUSION

Even though performance of the crossbred pigs in body weight and litter size seems encouraging, the body size of the pigs has been hindered greatly by parental epitasis. It should be noted that the inheritance of body size and litter size heteroses from the F_1 depends not only on the genetic structures of the parental breeds, but also on the amount of the hybrid vigour possessed by the F_1 itself.

It is feared that the backcross groups may have been disadvantaged in these traits because the F_1 did not fully maximize its heterotic potentials which would in turn affect the residual heterosis in subsequent generations. To adjust for this defect and any other possible shortfalls arising from the crossing between unimproved native and improved exotic breeds, the Back-and Crisscross Evaluation Technique ('BAC-CET') fully described and demonstrated by Omeje and Nwosu (1986) is hereby recommended (Fig. 1). In this strategy, the native pig is simultaneously crossed with two exotic or improved strains/breeds. F_1 crossbred pigs are backcrossed to the males of the parental breeds. The backcrosses are next intercrossed to generate four genetically different strains that will undergo selection. Selection shall be based on the performance of their progeny after crisscrossing.

Based on the results of the progeny testing, selected boars of one line strain will be mated to superior dams or sows of another line. It is hoped that BAC-CET will be an effective system because, it is designed to exploit all additive genes from the parental breeds as well as the dominance effects from the two improved strains. Any null, residual loci from 1 or 2 of the parental breeds particularly the native pig will be overcome by complementary association during the intercrossing. Thus, the final strain-cross pigs will be superior to the F_1 and even the parental breeds that gave rise to them.

ACKNOWLEDGEMENT

The authors would like to appreciate the invaluable contribution of Prof. S.I. Omeje and the suport and assistance of staff of the piggery unit. The permission by the University authority to make use of the facilities at the piggery is acknowledged.

REFERENCES

Crow, J.F., 1952. Dominance and Over-dominance In: Gowen, J.W. (Ed.). Heterosis. Hafner Publishing Co. New York, pp: 282-297.

Duncan, D.G., 1955. Multiple range and multiple F-tests. Biometrics, 11: 1-42.

Falconer, D.S., 1989. Introduction to quantitative Genetics, (3rd Edn.). Longman Scientific and Technical Essex, U.K.

Ghahabra, A.K., H.E. Nielson and P. Jensey, 1993. A Study of the incidence of stillbirths and abnormalities in Large white and Yorkshire litters. Ind. Vet., 60: 415-416.

Nwakpu, P.E. and S.I. Omeje, 2002. Heterosis of Early growth in native and Landrace pigs. Trop. J. Anim. Sci., 5: 65-74.

Omeje, S.I., 1985. Genetic basis of body weight heterosis in local by Gold-link Chicken Cross. Ph.D. Thesis, University of Nigeria, Nsukka.

Omeje, S.I., 1989. Development of the Nigeria chicken for improved production. A new approach. Invited paper, Agric symposium. Professors World Peace Academy, Ibadan, Nigeria.

Omeje, S.I. and C.C. Nwosu, 1986. A breeding programme involving local and exotic chickens for the development of new poultry breeds in Nigeria. Paper, 13th Annual Conference Genet. Soc. Nigeria Ibadan.

Sellier, P., 1976. The basis of crossbreeding in Pig. A Rev. Livest. Prod. Sci., 3: 203-226.

Sheridan, A.K., 1981. Crossbreeding and Heterosis. ABA, 49: 131-144.

Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods, 6th Edn. Iowa State University Press, AMES, IOWA, pp: 593.

Sansoucy, R., M.A. Jabbar, S. Ehui and H. Fitzhugh, 1995. The contribution of Livestock to food security and sustainable development. In: Round table on Livestock development Strategies for low income countries FAO, Rome and ILRI, Nairobi, pp: 182.

Williamson, G. and W.J.A. Payne, 1990. An Introduction to Animal Husbandry in the Tropics. 4th Edn. Longman, Inc. New York, pp: 194.

Winer, B.J., 1971. Statistical Principles in Experimental Design. 2nd Edn. Mc Graw Hill Ltd. Tokyo.

Wright, S., 1977. Evolution and the genetics of populations. Experimental results and evolutionary deductions. University of Chicago Press, Chicago, Vol. 3.

Yule, G.U. and M.G. Kendall, 1968. An Introduction to the Theory of Statistics. 14th Edn. Charles Griffin and Co. Ltd. London.