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Full Length Research

Heterosis and combining ability for body weight and morphometric traits in a diallel cross of Funaab alpha chickens

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ABSTRACT: This study was carried out to evaluate heterosis and combining ability for growth traits in a diallel cross of two strains of FUNAAB Alpha chickens. Sixty hens comprising thirty white plumage and thirty black plumage colours aged between 17-18 weeks were used. The experiment which lasted for 5 months, considered such growth traits as: Body Weight (BW), Body Length (BL), Chest Girth (CG), Shank Length (SL), Shank Circumference (SC), Comb Height (CH) and Comb Length (CL). The study was based on heterosis and diallel cross of growth traits (Hatch to 20 weeks of age). Data obtained were subjected to statistical analysis using IBM SPSS (Version 20, 2016). The result indicated that a significant disparity ($p<0.05$) existed between White plumage and Black plumage chickens in all characters studied. White FUNAAB Alpha was 12.46% heavier than the Black FUNAAB Alpha. In the main cross of W♂ x B♀ and reciprocal cross of B♂ x W♀, the reciprocal (B♂ x W♀) cross was 6.82% heavier than the W♂ x B♀ at day old, although, at 20 weeks of age, the W♂ x B♀ cross was 1.77% heavier than the B♂ x W♀ cross for body weight. The result of heterosis percentage revealed that heterosis estimates for body weight at hatch, 4 and 8 weeks of age was positive and higher in the black FUNAAB Alpha male x white FUNAAB Alpha female (B♂ x W♀). The main cross (W♂ x B♀) had superior heterosis for body length at hatch, 12 to 20 weeks of age.

Keywords: Diallel cross, general combining ability, heterosis, FUNAAB alpha, growth traits.

INTRODUCTION

Poultry improvement is genetically based on at least two different approaches and these are selection and crossbreeding (Adebambo *et al.,* 2011). Crossbreeding as a tool permits manipulating genetic variation in order to modify populations in such a manner that attempts to boost desired phenotype. The primary essence of crossing is to produce higher crosses to increase the performance of the developed local chickens and to combine diverse traits in which the breeds crossed were valuable for egg production and growth traits (González Ariza *et al.*, 2021; Soliman *et al.,* 2016). The poultry industry is known to be the biggest when it comes to livestock species and thus produces more than thirty per cent of animal protein (Adebambo *et al.* 1996; Olori, 1992). They exist within the poultry population and are extensively found under scavenging systems in most rural regions (Muchadeyi *et al*., 2007; Osei-Amponsah *et al*., 2010). Local chickens are generally strong and cope well through epidemics and various harsh environmental conditions (Addisu, 2012). In the last three decades, the Nigerian local chickens have been improved through crossbreeding with exotic breeds. These exotic breeds play a vital role in the improvement of economic characters in local chicken strains (Mohamed, 2003). Fayeye (2014) reported that crossbreeding results in increased heterosis in traits that are low in heritability. Poultry breeding using diallel crossing ensures a comprehensive genetic basis for the production of new strains or breeds and the discovery of superior crossbreds (Aly and El-Ella, 2006; Mottet and Tempio, 2017). High positive heterosis percentages for body weight at different ages among crossbreds can be evaluated to determine best-performing parents and mid-parents (Marangoni *et al.,* 2015). Thus, the objective of this study was to evaluate the heterosis/combining ability of different growth traits (body weight and body morphometric) from a complete diallel cross involving 2 strains of FUNAAB Alpha Chickens.

MATERIALS AND METHODS

Experimental location and study period

This experiment was conducted at the Poultry Unit of the Teaching and Research farm of Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Rivers State. The average rainfall in Port Harcourt is 200.45 m (Uko and Tamunobereton-Ari, 2013). The study lasted for 20 weeks.

Experimental birds

The birds used for this study were FUNAAB Alpha Strain. The FUNAAB Alpha birds are genetically improved Nigerian local chickens developed at the Federal University of Agriculture Abeokuta (FUNAAB) Ogun State by a PEARL Project. These birds were developed after generations of intensive selection within normal feather Nigerian local chickens and later crossbreeding with indigenous chickens of India (Adebambo, 1999). Sixty FUNAAB Alpha improved Nigerian local chickens comprising thirty (30) black and thirty (30) white plumage hens between 17 and 18 weeks of age were sourced from the Poultry Unit of the Federal University of Agriculture (FUNAAB) Abeokuta, Ogun State. The birds were randomly allocated into 6 replicate deep litter pens/strains for two weeks of acclimatization and later assigned into individual cages in a three-tier battery cage at 19 weeks of age.

Selection of parents and diallel cross

Six sires each from the white and black FUNAAB Alpha strains were selected from the population based on their evaluated semen quality traits. From the existing population, sixty hens were selected based on their body weight and egg production.

Diallel cross

The selected birds were allocated randomly into four breeding groups as follows: WW (W♂ x W♀), BB (B♂ x B♀), WB (W♂ x B♀), and BW (B♂ x W♀) respectively. Each breeding group consisted of three sires and fifteen dams making a total of 72 chickens altogether. For the mating procedure, the artificial insemination method was used to inseminate the dams in this study. A ratio of one sire to five dams in each group was used and this was replicated three times. The insemination was carried out using a micro-pipette set at 0.2µ. At the beginning of the experiment, semen was collected from the selected sire and inseminated into the oviduct of the dams in each breeding group. This was done thrice weekly to ensure high fertility.

Data collection

This study was designed such that data was obtained on growth traits.

Body weight and morphometric traits

Body weight and morphometric traits were measured and obtained from the progeny at intervals of 4 weeks (from hatch to 20 weeks of age). The variables among others measured include;

a. **Body weight:** The body weight of each bird was taken with the use of an electronic weighing scale in grams.
b. **Chest Girth:** This was measured as the width between two shoulder joints around the chest.
c. **Body length:** This was measured as the length between the lower ends of the rostrum maxillae (beak) to the caudal tail (coccygeal bone) without feathers from the body surface.

The body measurements were done using the description of Teguia *et al.* (2008) and Yakubu (2011). The amount of heterosis is measured as the deviation of the mean performance value of individuals from the mean of their parents. Heterosis in the F1 is thus estimated by HF1 = Ĥ1 - $\bar{P}$ where Ĥ1 is the mean of the F1 progeny and $\bar{P}$ is the mid-parent value. It is frequently expressed as a percentage thus;

% heterosis = $\frac{\hat{H}1 - \bar{P}}{\bar{P}} \text{ x } 100$ (Ibe, 1998)

Data analysis

Data were analyzed for variation between the crosses and within crosses (between progeny) using the multivariate analysis of general linear model procedure with genotype (WW, BB, WB, and BW) and Age (Hatch, 4, 8, 12, 16, and 20) as main effects. Interactions of these effects were also analyzed. Significant means at p<0.05 were separated using LSD.

Genetic parameter estimate

Heterosis % for cross $(W\ x\ B) = \left\{(W\ x\ B) - \frac{\{(WW+BB)\}}{2}\right\}/$ $\{(WW + BB)\}$ /2 x 100}

Table 1. Mean SE for growth traits at different studied ages from the diallel crossing of White and Black FUNAAB Alpha strains.

Trait	GG	Growth traits at different ages (weeks)						p-value		
		Day old	4	8	12	16	20	Strain	Age	S x A
BW	WW	42.93[b]	187.86[a]	578.07[b]	991.50[a]	1021.14[a]	1024.14[a]	0.000	0.000	0.005
	WB	41.00[c]	169.70[c]	548.67[d]	833.40[b]	844.10[b]	848.10[b]			
	BB	37.80[d]	151.60[d]	567.11[c]	750.78[d]	767.56[d]	771.33[d]			
	BW	44.00[a]	184.70[b]	612.80[a]	819.00[c]	828.60[c]	833.10[c]			
BL	WW	12.20[c]	21.82[a]	29.89[a]	37.72[b]	38.14[b]	38.51[b]	0.000	0.000	0.076
	WB	12.26[a]	20.77[c]	28.59[c]	38.95[a]	39.30[a]	39.62[a]			
	BB	11.77[d]	20.03[d]	29.00[b]	33.23[d]	33.57[d]	33.76[d]			
	BW	12.24[b]	21.50[b]	29.36[b]	37.30[c]	37.65[c]	37.89[c]			
CG	WW	9.92[b]	15.61[a]	22.47[a]	29.29[b]	29.73[ab]	29.86[b]	0.000	0.000	0.271
	WB	10.15[a]	15.08[c]	22.20[c]	30.41[a]	30.79[a]	30.90[a]			
	BB	9.35[d]	14.76[d]	22.40[ab]	26.26[d]	26.62[c]	26.71[d]			
	BW	9.82[c]	15.25[b]	22.26[b]	29.12[c]	29.52[b]	29.60[c]			
SL	WW	2.24[c]	3.95[b]	6.09[ab]	7.54[b]	7.75[a]	7.84[ab]	0.022	0.000	0.93
	WB	2.28[a]	3.90[c]	5.67[c]	7.61[a]	7.75[a]	7.86[a]			
	BB	2.20[d]	3.59[d]	6.02[b]	6.84[d]	7.02[c]	7.12[c]			
	BW	2.26[b]	4.03[a]	6.17[a]	7.42[c]	7.65[b]	7.74[b]			
SC	WW	1.85[c]	2.76[b]	3.54[b]	7.02[a]	4.44[b]	4.48[b]	0.315	0.000	0.787
	WB	2.05[a]	2.65[c]	3.64[a]	4.44[b]	4.52[a]	4.60[a]			
	BB	1.79[d]	2.46[d]	3.48[c]	3.94[d]	4.02[c]	4.07[d]			
	BW	1.94[b]	2.86[a]	3.45[d]	4.02[c]	4.08[bc]	4.12[c]			
CL	WW	0.000	1.14[b]	2.53[a]	3.63[a]	3.70[a]	3.79[a]	0.000	0.000	0.787
	WB	0.000	1.15[a]	2.27[b]	3.06[b]	3.17[ab]	3.28[b]			
	BB	0.000	0.93[d]	2.08[bc]	2.37[c]	2.47[c]	2.66[c]			
	BW	0.000	1.07[c]	2.07[c]	3.06[b]	3.16[b]	3.27[ab]			
CH	WW	0.000	0.25[a]	1.02[a]	1.79[a]	1.89[a]	1.99[a]	0.000	0.000	0.630
	WB	0.000	0.21[c]	0.80[c]	1.44[c]	1.54[c]	1.71[b]			
	BB	0.000	0.19[d]	0.82[bc]	1.13[d]	1.30[d]	1.51[c]			
	BW	0.000	0.24[b]	0.85[b]	1.51[b]	1.61[b]	1.73[ab]			

GG = Genotype group, BW = Body weight, BL = Body length, CG = Chest girth, SL = Shank length, SC = Shank circumference, CL = Comb length, CH = Comb height, WW = White White, WB = White Black, BB = Black Black, BW = Black White, S x A = Interaction of Strain and Age.

General Combining Ability (GCA): The general combining ability (GCA) values were calculated as the deviation of a specific genotype means from the overall mean for a trait estimated for the 4 diallel crosses. This implies that the GCA for (W x W) = {1/3*[(WW) + (W x B) + (B x W)] – 1/4* [(WW) + (BB) + (W x B) + (B x W)]}.

RESULTS AND DISCUSSION

Results in Table 1 showed that at different weeks of age, body weight differed significantly ($p<0.05$) among the four genetic groups. The white FUNAAB Alpha strain had a heavier day-old weight in comparison with the black FUNAAB Alpha strain. In all crosses with white FUNAAB Alpha was used as a dam, and heavier body weights at hatch and other age periods were noticed. The white FUNAAB Alpha (W x W parent genotype) was heavier (42.93 g) than the Black FUNAAB Alpha parental genotype (37.80 g) at day old. In the main cross of W♂ x B♀ and reciprocal cross of B♂ x W♀, the reciprocal (B♂ x W♀) cross was 6.82% heavier than the W♂ x B♀ at day old, although, at 20 weeks of age, the W♂ x B♀ cross was 1.77% heavier than the B♂ x W♀ cross all for body weight.

Table 2. Heterosis percentages of body weight and body morphometric for offspring at different studied ages from the diallel crossing of white (WW) and black (BB) FUNAAB Alpha strain.

Trait	GG	Growth traits at different ages (weeks)					
	♂ x ♀	Day old	4	8	12	16	20
BW	W x B	1.57	-0.02	-4.18	-4.33	-5.62	-5.53
	B x W	9.01	8.82	7.02	-5.99	-7.35	-6.54
BL	W x B	2.29	-0.74	0.03	9.76	9.61	9.64
	B x W	2.13	2.74	-0.29	5.14	5.01	4.86
CG	W x B	5.35	-0.69	-1.05	9.49	9.28	9.25
	B x W	1.92	0.42	-0.78	4.84	4.77	4.65
SL	W x B	2.70	3.45	-6.36	5.84	4.94	5.08
	B x W	1.80	6.89	1.89	3.19	3.59	3.48
SC	W x B	12.64	1.53	3.70	-18.98	6.86	7.60
	B x W	6.59	9.57	-1.71	-26.64	-3.55	-3.63
CL	W x B	0.00	11.1	-1.52	2.00	2.76	1.71
	B x W	0.00	-10.144	-10.19	2.00	2.43	1.39
CH	W x B	0.00	-4.54	-13.04	-1.37	-3.45	-2.29
	B x W	0.00	9.09	-7.61	3.42	0.94	-1.14

GG = Genotype group; BW = Body weight; BL = Body length; CG = Chest girth; SL = Shank length; SC = Shank circumference; CL = Comb length; CH = Comb height; W♂ x B♀ = White male x Black female; B♂ x W♀ = Black male x White female.

In all the growth traits studied, the White FUNAAB Alpha strain had better and higher significance than the Black FUNAAB Alpha strain. This may indicate that the underlying carotenoid pigmentation for white colour could possibly be linked with genes that favour the development of the various traits (body weight, body length, etc) studied (Evans and Sheldon, 2015). Body length at different weeks of age was significantly different ($p<0.05$) among the four genetic groups, with the white FUNAAB Alpha (12.20 cm) having a superior value than the black FUNAAB Alpha (11.77 cm), although the main cross (W♂ x B♀) had higher value of 12.26 cm than the reciprocal cross (B♂ x W♀) with value of 12.24 cm. A similar trend was noticed in all other morphometric traits (CG, SL, SC, CL and CH) at different ages from the diallel crossing of White and Black FUNAAB Alpha strains.

Heterosis estimates for body weight and morphometric traits are presented in Table 2. The result shows that heterosis estimates for body weight at hatch, 4 and 8 weeks of age were positive and higher in the Black FUNAAB Alpha male x White FUNAAB Alpha female (B♂ x W♀). At 12 – 20 weeks of age, negative heterosis was obtained. Negative heterosis was obtained at 4 – 20 weeks of age for the main cross (W♂ x B♀). The main cross (W♂ x B♀) had superior heterosis for body length at hatch, 12 to 20 weeks of age.

The result for estimates of general combining ability (GCA) is presented in Table 3. GCA estimates were all positive for body weight in W♂ x W♀ for hatch, 4 to 20 weeks of age while they were all negative in B♂ x B♀ cross in all the ages. A similar trend was noticed in body length except for week 4 (0.263) which was positive for BB cross. Estimates of GCA for chest girth recorded positive estimates for the W♂ x W♀ cross except week 8 (-0.023) which was negative; however, all the ages for the B♂ x B♀ cross were negative. Similar observations were made with respect to shank length, shank circumference, comb length and comb height. As coined by Kleyn and Ciacciariello (2021), heterosis can be seen as the explanation of increased size, vigour, speed of improvement, fruitfulness, resistance to disease and to insect pests or to climatic stress of any kind by crossbred organisms as linked with corresponding inbred (Fayeye, 2014). Typically, heterosis refers to the mean performance of hybrid progeny relative to the mid-parent value. It could be individual, paternal or maternal. It is individual, if the relative performance of the progeny is not attributable to maternal, paternal or sex-linked effect, whereas it is paternal when there is any advantage of progeny performance arising from using crossbred and purebred sires (Khumpeerawat, *et al.,* 2021). It is maternal if it refers to the relative advantage of the progeny of crossbred dams over the progeny of purebred dams (Ibe, 1998).

Although a series of breeding programs are ongoing, it is essential to come up with specific breeding programs that will permit improving performance of local chickens. In order to genetically improve the performance of these local chickens, selection and crossbreeding are essential approaches. Selection could take a long time and requires technology which lacking in developing countries. Hence crossbreeding can be seen as a primary tool that allows manipulating genetic variation in an attempt to optimize desired phenotype (Idowu *et al*., 2021). Crossbreeding therefore is a vital aspect of modern breeding programs in poultry that exploits genetic variations. The primary purpose of crossing is to produce superior crosses or

Table 3 General and specific combining abilities of growth traits at different ages from the diallel crossing of white and black FUNAAB Alpha strains.

Trait	GG	Growth traits at different ages (Weeks)					
		Day Old	4	8	12	16	20
BW	WW	1.211	7.288	3.183	32.630	32.596	32.612
	BB	-0.502	-4.799	-0.470	-47.610	-51.93	-51.658
BL	WW	0.112	0.333	0.07	1.190	1.198	1.228
	BB	-0.028	0.263	-0.226	-0.306	-0.325	-0.355
CG	WW	0.153	0.138	-0.023	0.836	0.848	0.853
	BB	-0.036	-0.145	-0.046	-0.173	-0.188	-0.197
SL	WW	0.015	0.093	-0.011	0.171	0.174	0.173
	BB	0.001	-0.027	-0.033	-0.062	-0.068	-0.06
SC	WW	0.039	0.074	0.016	0.305	0.081	0.083
	BB	0.019	-0.026	-0.004	-0.722	-0.059	-0.054
CL	WW	0.000	0.048	0.053	0.220	0.218	0.196
	BB	0.000	-0.022	-0.097	-0.200	-0.192	-0.010
CH	WW	0.000	0.011	0.018	0.113	0.095	0.091
	BB	0.000	-0.009	-0.596	-0.107	-0.102	-0.069

GG = Genotype group, BW = Body weight, BL = Body length, CG = Chest girth, SL = Shank length, SC = Shank circumference, CL = Comb length, CH = Comb height, WW = White x White, BB = Black x Black, WB = White x Black, BW = Black x White.

breeds that promote reproductive as well as productive traits (Hanafi and Iraqi, 2001; Khumpeerawat, *et al.,* 2021; Nganvongpanit, *et al*., 2020).

The estimation of crossbreeding effects (general combining ability (GCA) and specific combining ability (SCA), direct genetic effect, heterotic effect, maternal effect and reciprocal effect) is therefore of foremost importance (Marangoni *et al.,* 2015). The combining ability of paternal populations can be tested using full diallel crossing. To designate the average performance of an individual line in hybrid combination, general combining ability is engaged whereas specific combining ability is applied in cases in which certain combinations, do relatively better or worse than would be required on the basis of the average performance of the lines involved (Tongsiri *et al*., 2019). According to Saadey *et al.* (2008) and Nganvongpanit, *et al*., 2020), the combining ability also helps to locate the most appropriate combiner that may be used to exploit hybrid vigour. Several reports have it that GCA (additive genetic effect) is high and vital as well as SCA (non-additive effect that involves dominance and epistasis) for body weight at different ages in chickens (Chomchuen *et al.*, 2022; Razuki and Al-Shaheen, 2011).

Conclusion and Recommendation

The diallel analysis of the White and black FUNAAB Alpha strain showed that body weight was affected by genetic group. Crossing between white and black FUNAAB Alpha resulted in improved body weight at varying ages. The white FUNAAB Alpha gave the best estimate for heterosis and general combining ability. The White FUNAAB Alpha strain should be produced in commercial quantity as it is strong, attractive, and not prone to regular disease invasion if properly managed and has the capacity to produce both meat and good quality eggs.

The FUNAAB Alpha should be crossed with other strains that are genetically divergent from it so as to reduce inbreeding depression which may lead to low hybrid vigour.

Diverse breeding programmes that would address hybrid vigour should be setup mainly for improving the FUNAAB Alpha strains and other Nigerian local chickens and this should involve crossing with genetically heterozousity parents so as to achieve larger heterosis. Therefore, the use of white FUNAAB Alpha as dam and both sire parents provided the most balanced combination and improved body weight. It is therefore recommended for use as parent in other to exploit their vigour for body weight improvement.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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