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Full Length Research

Maternal, additive and dominance effects of main and reciprocal crossbred Turkeys reared in humid tropics

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ABSTRACT: Maternal and dominance effects, General Combining Ability (GCA) and Specific Combining Ability (SCA) were used to determine the influence of additive and non-additive genes effects on linear body traits, using a total of two hundred and fifteen (215) day-old poults of three strains of local turkey crossbred in the humid tropics. A full diallel crossing experiment was conducted using three phenotypes of indigenous turkeys with the plumage colour: black, white and lavender (spotted). A randomised complete block design (RCBD) was also used to analyse the data with phenotypic class as a major factor and batch as a block. The data obtained were subjected to analysis of variance (ANOVA). The result obtained in the study showed that GCA was significant for BL, WL, DS and SL and non-significant for BW, BRW, KL and NL with values ranging from – 0.34 to 0.640, respectively. SCA was also significant for BL, BW, BRW, KL and SL but non-significant for WL, DS and NL, ranging from 2.981 to 8.324. It was concluded that the significance (P<0.05) differences observed for most LBMs and BW in different ages (weeks) for GCA and SCA indicates that non-additive effects of genes could be improved genetically through selection and crossbreeding of BxS, BxW and WxS genotypes to bring about genetic improvement for BW and LBMs and by improving the environment. The result also indicates higher maternal and additive effects on body weight among the crossbreds. This also implies that poults from BxW and WxB dams are preferred for body weight compared to poults from BxW and BxS because of negative value estimates obtained in their maternal effect.

Keywords: Dominance effect, general combining ability, maternal, linear body traits, specific combining ability, Turkey.

INTRODUCTION

Genetic gains could be due to improvement within the primary breeding lines (additive genetic variation) or exploited through heterosis in the crosses used to produce the commercial turkeys. Several studies have shown an increase in body weight (McCartney *et al.,* 1968; Nestor, 1977, 1984; Nestor *et al*., 1996), breast width (Nestor *et al*., 1969) and shank length (Nestor *et al*., 1985) due to genetic selection within lines of several strains. Genes could impart additive and non-additive effects on traits. While additive gene action is transmissible from parents to their offspring, non-additive gene action (dominance and epistasis) is not. Consequently, the proportion of total phenotypic variance that is additive is used as a measure of heritability (Obasi and Ibe, 2008).

Genetic progress can be attained by selection and crossbreeding (Adebambo *et al*., 2011). The test for good combining abilities is developed by generating a diallel cross, which is a set of possible combinations between several genotypes and general populations and analysis of data from such crosses (Hayman, 1954). The combining ability analyses help to identify the desirable combiners that may be utilised to exploit heterosis (Saadey *et al*., 2008). Gardner and Eberhardt (1966) defined general combining ability (GCA) as the average performance of a line in different hybrid combinations.

The estimates of general combining ability (GCA) reflect the importance of additive gene effects of breeds on body weight at different ages (Afifi *et al*., 2002). The variation in GCA is owing to additive genetic variance. Specific combining ability (SCA) refers to a cross produced by a pair of lines (Adebambo *et al.,* 2011). Exploitation of heterosis is a major reason for crossbreeding in farm animals (Ibe *et al.,* 2005). Utilisation of this phenomenon has led to the development of high-quality breeds of livestock in both poultry and other farm animals. Usually, characters that suffered a reduction in inbred status are often restored or tend to be restored on crossing (Falconer, 1981). Commercial turkey breeders have made major improvements in growth traits of the modern turkey (Havenstein et al., 2004).

MATERIALS AND METHODS

Location of study

The study was conducted in the Poultry Unit of the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State. Umudike lies between latitude 05° 29¹ N, longitude 07° 33¹ E and an altitude of 122 m above sea level. The town is within the humid rain forest zone of South-Eastern Nigeria and has a bimodal rainfall pattern with a total annual rainfall range of 1700 mm to 2100 mm. The minimum and maximum daily temperatures of the area range from 18.6 to 23°C and from 26 to 36°C during the rainy and dry seasons, respectively, while the humidity ranges from 57.0% to 91.0% depending on the season of the year. The climatic data were taken from the meteorological station of the National Root Crops Research Institute, Umudike.

Mating design

The mating design was as follows:

Pure crosses: Black male x Black female, White male x White female, Lavender male x Lavender female.

Main (Direct) Crosses: Black Male x White female, Black male x Lavender female, White male x Lavender female.

Reciprocal Crosses: White male x Black female, Lavender male x Black female, Lavender male x White female.

Management of experimental birds

A total of 86 adult local turkeys of three phenotypic classes based on colour (Black, White and Lavender) were used as a parent population: 28 Black, 28 White and 30 Lavender phenotypes to generate the 251 F_1 poults for the study. They were brooded differently according to phenotypic group (Black, White and Lavender) from day-old to 6 weeks in a battery cage system, after which they were transferred to a deep litter pen at 6 weeks of age and reared till week 24. Dry wood shavings were used as litter material. Fresh, clean water was given *ad libitum* to the poults during this period. Routine management operations were carried out daily. Prophylactic antibiotics and anticoccidial drugs were administered to the birds every month for six months. The birds were also dewormed. Feeds were provided in adequate quantities to the poults twice daily (morning and evening) and drinking water *ad libitum*. Poults (0 - 6 weeks) were fed starter mash containing 28% crude protein and 2800 kcal ME/kg (as labelled). Growing turkeys (7-20 weeks) were fed growers mash containing 20% crude protein and 3000 kcal ME/kg (as labelled). Laying hens (21-30 weeks) were fed layers mash containing 18% crude protein and 3200kcal ME/kg (as labelled) at 5% egg production. At 16 weeks of age, sexing was done, and all the males were transferred to different pens for mating and crossing with other phenotypic groups. The massage method was used for the collection of semen from the mature selected males at the farm during the mid-day hours of 12-1 pm, and inseminated artificially. Eggs produced by the base population turkey hens were collected on a daily basis and identified properly with markers, and incubated for 28 days in four (4) sets and hatched to generate the F1 progenies. The incubator had a relative humidity of 80%, a temperature of 55°C and proper ventilation.

Parameters measured

Body weight (BWT), Body length (BDL), Shank length (SL), Keel length (KL), Wing length (WL), Breast width (BW), Drumstick length (DL) and Neck Length (NL). All parameters except BWT were measured weekly using a tailor's tape calibrated in cm, while body measurement was taken with a sensitive table weighing scale.

Statistical analysis

Randomized complete block (RCBD) with phenotypic class as factor of interest and batch as block and data analyzed by analysis of variance (ANOVA) to test the null hypothesis that there were significant differences among the various phenotypic groups (the crosses) with respect to body weight and all the linear body measurements studied as given in expression (1). The statistical model for analysis of variance is given as:

$$Y_{ijk} = \mu + H_i + P_j + e_{ijk} \qquad \dots (1)$$

Where: Y_{ijk} = k^{th} observation in the i^{th} block and the j^{th} phenotypic class, i.e. single observation; μ = Overall

Table 1. Estimation of maternal, additive and dominance effect.

Mean	AMm	AMf	Arm	ARf
Maternal effect	+1	+1	-1	-1
Additive effect	+1	0	-1	0
Dominance	+1	-1	-1	+1

Where: +1, 0 and -1 are orthogonal contrast coefficients, AMm = Mean of male progeny of main cross, AMf = Mean of female progeny of main cross, ARm = Mean of male progeny of reciprocal cross, ARf = Mean of female progeny of reciprocal.

mean; H_i = effect of the i^{th} batch (Block) (i = 1,…, 4); P_j = effect of j^{th} phenotypic class (j = 1,…, 9); e_{ijk} = Random error, assumed to be independently, identically and normally distributed with zero mean and constant variance [iind $(0,\sigma^2)$].

The method of Griffing (1956) was used to further examine the diallel cross using the statistical model of combining ability as described by Siewerdt and Dionello (1991). The general combining ability, specific combining ability and reciprocal effect were estimated using expression (2) as given by Obasi and Ibe (2008).

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_{ij} + 1/n \sum e_{ijk} \quad \ldots (2)$$

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; e_{ij} = Error associated with k^{th} individual observation.

Expressions (3) and (4) were used to estimate GCA and SCA, respectively.

$$GCA,\ _{i/j} = 1/2p\ (Y_i + Y_{.i}) - 1/p^2 Y \quad \ldots\ldots (3)$$

$$SCA,\ s_{ij} = ½\ (Y_{ij} + Y_{ji}) – 1/2p\ (Y_{i.} + Y_{.i} + Y_j. + Y_{.j}) \quad \ldots\ldots.(4)$$

Where p = number of lines/breeds involved in the crosses.

Estimation of maternal, additive and dominance effects

The estimation of maternal, additive and dominance effects was computed using Orthogonal contrasts according to Lowry (1992) as shown in Table 1.

RESULTS AND DISCUSSION

The maternal, additive and dominance effects on body weight of BxS and SxB crosses of domestic turkey are presented in Table 2. There were no significant ($p>0.05$) differences in maternal, additive and dominance effects at all ages for both the main and reciprocal crosses, although positive values were observed in the additive effect for both crosses at ages 4, 8, 12, 16, 20 and 24. This could be due to the fact that maternal and sex-linked effects are likewise unlikely to explain differences in the observed phenotypes of the progenies due to a non-significant effect visible as reported by Okoro *et al*. (2012).

Nestor *et al.* (2005) using orthogonal contrast estimated reciprocal and additive genetic effects in a cross involving a commercial turkey line and F-line and found no significant reciprocal and effects on body weight but significance effect was observed on linear body measurements. Iraqi *et al*. (2011) also reported significant reciprocal, maternal and sex-linked effects on growth traits of crosses involving four breeds of chicken.

Lalev *et al*. (2014) reported that maternal effect had a substantial effect on body weight at different ages in a crossbreeding experiment involving white Plymouth Rock lines of chicken. Negative values obtained by maternal effect indicate the non-relevance effect on the prediction of progeny performance. Positive additive effects observed are similar to the results of Khalil *et al.* (1999), who reported highly significant direct additive effects ranging from 4.9% to 10.2% for body weight in indigenous chicken breeds.

Table 3 presents the effects of ME, AE and DE on the body weight of BxW and WxB crosses. There were ($p<0.05$) significant differences for ME, AE and DE in weeks 4 and 8, although the values of AE were positive and higher. Significant differences ($p<0.05$) were observed in ME and AE effects in weeks 12, 16, 20 and 24. DE showed no significant difference in weeks 12 to 24.

The result indicates higher maternal and additive effects on body weight among the crossbreds. This also implies that poults from BxW and WxB dams are preferred for body weight compared to poults from BxW and BxS because of negative value estimates obtained in their maternal effect. The significant maternal effects in week 12-24 are similar to the findings of Iraqi *et al*. (2011), who reported maternal effects for body weight ranging from -5.67% to 0.06% for crossbreeding involving Matrouh and Indhas chicken breeds.

Khalil *et al*. (1999) reported ME in favour of White leghorn on Body Width with estimates ranging from -7.2 to

Table 2. Maternal, additive and dominance effects of body weight of BxS and SxB crosses of the domestic Turkeys.

Age (Weeks)	Main (Direct) cross [BxW (g)]		Reciprocal cross [WxB (g)]		Maternal Effects (ME)	Additive Effects (AE)	Dominance Effects (DE)
	AMm	AMf	ARm	ARf			
4	660	650	665	655	-10.00	-5.00	0.00
8	1206	1105	1217	1188	-94.00	-11.00	72.00
12	1881	1733	1897	1764	-47.00	-16.00	15.00
16	2960	2856	2990	2845	-19.00	-30.00	-41.00
20	3260	3172	3320	3278	-166.00	-60.00	46.00
24	3630	3489	3754	3533	-168.00	-124.00	80.00

BxS = Black x Lavender, SxB = Lavender x Black, AMm = Mean of male progeny of Main Cross, AMf= Mean of female Progeny of Main cross, ARm = Mean of male progeny of Reciprocal Cross, ARf = Mean of female progeny of Reciprocal Cross, ME= Maternal effect, AE= Additive effect, DE= Dominance effect.

Table 3. Maternal, additive and dominance effects of body weight of BxW and WxB crosses of domestic turkeys.

Age (Weeks)	Main (Direct) cross [BxW (g)]		Reciprocal cross [WxB (g)]		Maternal Effects (ME)	Additive Effects (AE)	Dominance Effects (DE)
	AMm	AMf	ARm	ARf			
4	662	655	664	659	-6.00*	-2.00*	2.00*
8	1208	1134	1215	1172	-45.00*	-7.00*	31.00*
12	1883	1754	1893	1766	-22.00*	-10.00*	2.00
16	2632	2528	2651	2543	-34.00*	-19.00*	-4.00
20	3262	3187	3312	3259	-122.00*	-50.00*	22.00
24	3633	3509	3750	3622	-230.00*	-117.00*	-4.00

BxS = Black x Lavender, SxB = Lavender x Black, * = p<0.05, ** = p <0.001, AMm = Mean of male progeny of Main Cross, AMf= Mean of female Progeny of Main cross, ARm = Mean of male progeny of Reciprocal Cross, ARf = Mean of female progeny of Reciprocal Cross, ME = Maternal effect, AE = Additive effect, DE = Dominance effect.

Table 4. Maternal, additive and dominance effects of body weight of WxS and SxW crosses of domestic turkeys.

Age (Weeks)	Main (Direct) cross [WxS (g)]		Reciprocal cross [SxW (g)]		Maternal Effects (ME)	Additive Effects (ME)	Dominance Effects (DE)
	AMm	AMf	ARm	ARf			
4	663	655	667	658	-7.00	-4.00	-1.00
8	1210	1159	1218	1134	17.00**	-8.00	33.00**
12	1886	1771	1895	1790	-28.00**	-9.00	10.00*
16	2638	2521	2653	2542	-36.00**	-15.00	6.00*
20	3263	3142	3317	3282	-194.00	-54.00	86.00
24	3637	3553	3750	3682	-242.00	-113.00	16.00

WxS = White x Lavender, SxW = Lavender x White, * = p<0.05, ** = p<0.001, AMm = Mean of male progeny of Main Cross, AMf = Mean of female Progeny of Main cross, ARm = Mean of male progeny of Reciprocal Cross, ARf = Mean of female progeny of Reciprocal Cross, ME = Maternal effect, AE = Additive effect, DE = Dominance effect.

10%. Saadey *et al*. (2008) reported positive estimates for maternal breed effects on body weight traits for crosses obtained from Sania and White Leghorn Chicken. Nestor *et al.* (2005) using orthogonal contrast estimated reciprocal and additive genetic effects in a cross involving a commercial turkey line and F-line and found no significant reciprocal and effects on body weight but significance effect was observed on linear body measurements. Iraqi *et al*. (2011) also reported significant reciprocal, maternal and sex-linked effects on growth traits of crosses involving four breeds of chicken.

Table 4 presents the ME, AE and DE for BW of WxS and SxW crosses of domestic turkey.

There was no significant effect for ME, AE and DE in week 4 for both main and reciprocal crosses. However, ME and DE were significantly different (p<0.05) in weeks 8, 12, 16 and 20. The additive effect was not significant (p>0.05) from week 4 to 24. ME and DE also showed no significant (p>0.05) difference in week 24.

The result of this study shows significant ME, suggesting that using SxW as a dam line (main cross) resulted in significantly better mothering ability. Also, non-additive gene effects could be exploited through crossbreeding to bring about improvement in body weight. Therefore, a planned crossbreeding programme using WxS and SxW breeds to exploit maternal effect could be adopted to achieve good mothering ability as well as high body weight improvement. The results of these studies are similar to the results of Saadey *et al*. (2008), who reported positive estimates for maternal breed effect for body weight for crosses obtained from Sania and White Leghorn Chicken.

Khalil *et al*. (1999) reported ME in favour of White Leghorn on Body Width with estimates ranging from -7.2 to 10%. Saadey *et al*. (2008) reported positive estimates for maternal breed effects on body weight traits for crosses obtained from Sania and White Leghorn. Nestor *et al.* (2005) used orthogonal contrast to estimate reciprocal and additive genetic effects in a cross involving a commercial turkey line and F-line and found no significant reciprocal effects on body weight, but significant effects were observed for linear body measurements. Iraqi *et al*. (2011) also reported significant reciprocal, maternal and sex-linked effects on growth traits of crosses involving four breeds of chicken.

General combining ability

GCA was significant ($p<0.01$) for BL, WL, DS and SL and non-significant ($p>0.01$) for BW, BRW, KL and NL with ranges from 0.111 to 24.218, respectively. This implies that additive gene action governs BL, WL, DS and SL and not for the other traits, which may be governed by genes with non-additive effects. Hence, those characters governed by genes with additive effects are expected to respond to selection for their genetic improvement, since their heritability values are expected to be moderate to high. GCA estimates were highest for drumstick length in the white breed and significant in seven out of eight traits studied. White phenotypes were highest in one trait, while lavender phenotypes (spotted) had the lowest estimates in all traits studied. This suggests that the white breed has the highest preponderance of genes, which have additive effects on the growth traits. The indication is that white phenotype turkeys could possibly increase growth performance because of their higher GCA values. This result is similar to the early findings of Obasi and Ibe (2008) who reported significant GCA for body length, heart girth, ear length and tail length in a full diallel cross involving three breeds of rabbits (New Zealand White, Dutch and Chinchilla. This result obtained in this study contradicts the works of Okoro *et al.* (2012), who reported non-significant GCA values for BWT, BRW, DS, SL, and BL in full diallel crosses between three locally adapted parental turkey lines comprising of black, bronze and white plumage-coloured genotypes. McCartney and Chamberlin (1961) concluded that genetic variance was much more important than non-additive genetic variance for BWT and body conformations in turkeys using diallel crosses. Adebambo *et al.* (2011) reported best GCA values for BW from weeks 1 to 12, with values ranging from 19.49 ± 0.42 to 769.30 ± 4.80 in a full diallel combination involving four breeds of chicken (Anak Titan, Alpha, Gririraja and normal indigenous chickens). Musa *et al.* (2015) reported a significant GCA, SCA and RE in a full diallel crosses involving 3 genotypes of Nigeria indigenous chickens: normal (N), frizzle (F) and naked-neck (Na) with GCA values ranging from -0.03 to 8.88 from day old to week 20 indicating importance of additive gene effects on body weight.

Specific combining ability

SCA estimates were significant ($p<0.01$) for BL, BW, BRW, KL and SL but non-significant for NL, DS and NL. The significant SCA is an indication of non-additive gene action for these traits. The implication is that BW, BL, BRW, KL and SL can be improved genetically through appropriate crossing, utilising non-additive gene effects like dominance and epistasis involving dominance. The highest and significant SCA values were observed in BW (-105.131) in WxS crosses, followed by BL (-1.309) and WL (-1.106). SCA for WxS was highest for all the traits studied, namely BW, BL, WL, BRW, DS, SL, KL and NL. This indicates that non-additive gene effects could be exploited to genetically improve the traits in BxS, WxS and BxW crosses since most of the traits showed significant SCA in all the crosses.

The result also suggests that BxS performed generally well in crosses with either White or Lavender (W or S). This findings is similar to the results of Okoro *et al*. (2012), and Obasi and Ibe (2008) who reported significant SCA values for BW and linear body traits in a full diallel crosses involving three turkey lines namely; black, bronze and white plumage colour genotypes and three breeds of rabbits namely; New Zealand White, Dutch and Chinchilla, respectively indicating importance of non-additive gene effects which could be exploited genetically to improve the body weight and linear body traits. Musa *et al.* (2015) also reported that FxNa (frizzle x naked neck) chickens gave significant SCA values for body weights in weeks 4 to 20. Similarly, Adembabo *et al.* (2011) reported SCA values for breast girth (BG) and Tibia length (TL) with values ranging from 7.43 ± 0.11 to 0.86 ± 0.30 in weeks 1 to 20.

Reciprocal effect

Reciprocal effects were significant only in BL, BRW and DS for BxW crosses (Table 5). This significant estimate obtained for RE at week 20 of age implies that there was variation owing to sex-linked genes and maternal effect for the BxW crosses. Non-significant and negative RE values were observed for BxW, BxS and WxS cross on BW, BL, WL, BRW, DS, SL, KL and NL. This suggests that BxS and WxS may be used as sire and dam in planned cross-

Table 5. Estimates of general combining ability, specific combining ability and reciprocal effects for growth traits of 3 Strains of Domestic Turkeys in week 20

Parameter	BW (g)	BL (cm)	WL (cm)	BRW (cm)	DS (cm)	SL (cm)	KL (cm)	NL (cm)
GCA_{Black}	24.218	0.312*	0.261*	0.238	0.155*	0.131*	0.112	0.140
GCA_{White}	24.188	0.312*	0.263**	0.237	0.158*	0.113*	0.112	0.140
$GCA_{Lavender}$	24.208	0.312*	0.264**	0.238	0.158*	0.114*	0.111	0.139
$SCA_{Black, White}$	-101.801*	-1.309**	-1.099	-0.997**	-0.654	-0.523	-0.467**	-0.555
$SCA_{Black, Lavender}$	-101.719*	-1.308**	-1.105	-0.997**	-0.661	-0.489	-0.468**	-0.584
$SCA_{White, Lavender}$	-105.131*	-1.309**	-1.106	-0.997**	-0.661	-0.488	-0.467**	-0.585
$RE_{Black, White}$	- 0.025	-0.455*	-1.015	-0.390*	-0.110*	-0.175	-0.020	-0.030
$RE_{Black, Lavender}$	- 0.030	-0.505	-1.030	-0.410	-0.120	-0.005	-0.040	-0.045
$RE_{White, Lavender}$	-0.027	-0.460	-0.015	-0.395	-0.020	-0.160	-1.820	-0.030

* = p <0.05 ** = p <0.01. GCA = general combining ability, SCA = specific combining ability, RE = reciprocal effects. BW= body weight, SL = shank length, NL = neck length, BRW = Breast width, BL = body length, KL = keel length, WL = wing length and DS = drumstick length.

breeding programmes. The absence of significance RE indicates that there are no sex-linked or maternal effects exhibited by the BxS and WxS crosses. This result is in line with the findings of Okoro *et al.* (2012), who reported non-significant RE on BW and linear body traits in a full diallel experiment involving three lines of turkeys, black, bronze and white plumage-coloured genotypes. Ibe *et al.* (2005) reported no significant RE for BW and all LBMs in a full diallel experiment involving three breeds of rabbits. New Zealand White, Dutch and Chinchilla. However, Nestor *et al.* (2005) reported a significant RE for SL in male and female turkeys in a reciprocal cross of a commercial sire line and a line selected for long-term increased 16-week body weight. Musa *et al.* (2015) reported a significant effect of RE at hatch and 12 weeks of age in a full diallel experiment involving three genotypes of Nigerian indigenous chicken, namely, normal, frizzle and naked-neck.

Conclusion

It was concluded that the significance (p<0.05) differences observed for most LBMs and BW in different ages (weeks) for GCA and SCA indicates that non-additive effects of genes could be improved genetically through selection and crossbreeding of BxS, BxW and WxS genotypes to bring about genetic improvement for BW and LBMs and by improving the environment. The result also indicates higher maternal and additive effects on body weight among the crossbreds. This also implies that poults from BxW and WxB dams are preferred for body weight compared to poults from BxW and BxS as a result of negative value estimates obtained in their maternal effect.

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