Genetic parameter estimates (full sib and half sib analysis) of fertility and hatchability in two strains of Rhode Island chickens

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Abstract

A study was conducted to estimate the genetic parameters of fertility and hatchability in two strains of Rhode Island Red (RIR) Chickens denoted as Strain A and Strain B respectively using the full-sib (sire +dam variance) and maternal half-sib (dam variance) components. The birds were obtained from the selected populations of RIR Chickens kept at the poultry breeding programme of National Animal Production Research Institute, Shika, Zaria, Nigeria. Settable eggs were collected from mating 28 cocks to 252 hens in a ratio of 1cock:9 hens from each strain. Eggs were pedigreed according to sire and dam. Results showed that values obtained for number of egg set (EGGSET), number of fertile eggs (NFERT), number of hatched chicks (NHATCH), percentage of chicks hatched from total eggs set (PHATCH) and percentage of chicks hatched from fertile eggs (PHATCHBL) were all higher in strain A than strain B. Heritability estimates obtained from the full-sib and maternal half-sib analysis ranged from medium to high for the two strains (0.24-0.96). The maternal half sib estimates were higher (0.40-0.96) than the estimates obtained from full sibs (0.24- 0.48). Genetic and phenotypic correlations obtained for both strains were positive and similar regardless of method of estimation. Genetic correlations between EGGSET and PFERT were low in strain A using both full-sib and maternal half-sib analyses (0.09-0.14). Phenotypic correlations between EGGSET and PFERT, PHATCH and PHATCHBL were also low in both strains and regardless of method of analyses. Moderate to high heritability estimates suggest that genetic improvement can be obtained by selection of these reproductive traits. The full-sib analysis for estimating heritability will be preferred since it is assumed that only additive genetic variance contributes to the covariance between family members.

Keywords: Rhode Island Red Chickens, genetic parameters, fertility, hatchability

Introduction

Fertility and hatchability are the most important determinants for producing more chicks from a given number of breeding flocks within a given period. Fertility in poultry is traditionally regarded as an independent trait either of the male or the female, but genetic and non-genetic factors originating from both the male and female affect egg fertilization and embryo development (Brillard, 2003). Fertility of an individual egg is also a function of the genotype of the embryo, to which both parents contribute. Therefore, both paternal and maternal components should be accounted for simultaneously when analyzing fertility.

Factors affecting fertility which originate from the male include several sperm quality traits such as sperm metabolism, semen concentration, sperm motility, and the percentage of abnormal or dead sperm cells (Wilson *et al.,* 1979). Behavioral factors include the male's ability to successively mate with the hens efficiently, which may be affected by leg problems (Brillard, 2003) in the event of uncontrolled growth. Sperm quality traits are believed to be moderately heritable (Ansah *et al.*, 1985), whereas behavioral traits usually have a low heritability (Siegel, 1965). Factors originating from the female include egg quality, behavioral and physiological factors such as prevalence of sperm storage tubules (SSTs) (Brillard, 2003).

Fertility and hatchability are inter-related heritable traits that have variations among breeds and varieties. Hatchability is the rate of hatching of incubated or fertile eggs into viable chicks. It represents the number of eggs hatched into viable chicks after 21 days of incubation. Hatchability is determined either on the basis of all eggs set or of fertile eggs set after candling on the eighteenth day of incubation. Hatchability is not an easy trait to measure partly because of the considerable variation between eggs of different strains in the time required in the incubator for the chicks to hatch. The ability of the chick to hatch is superficially a simple characteristic; nevertheless in biological terms, it is extremely complex. Alternatively, the zygote may have formed but failed to develop beyond a specific point for one of a variety of reasons (Wilson, 1997).

Zygote development and thus hatchability are traits of the embryo influenced by maternal effects (Gowe *et al.*, 1993). However Sexton and Randen (1988) indicated that the sire exercised an appreciable influence on the level of hatchability inherited by his daughter. It may be possible therefore to demonstrate differences in transmitting ability among dams mated to the same sire.

Estimates of the genetic parameters such as heritabilities and genetic correlations of traits related to fertility and hatchability are needed to determine the most appropriate selection criteria.

Heritability can be estimated in several ways from data in a hierarchical design with a random sample of progeny from each dam and a random sample of dams mated to each sire also chosen at random (each dam being mated to only one sire). The appropriate model for this can be designated as:

$Y_{ijk} = \mu + S_i + D_{ij} + e_{ijk}$

where

Y_{ijk} is the measurement on the k^{th} progeny of the j^{th} dam mated to the i^{th} sire,

μ is the population mean, S_i is the effect of the i^{th} sire,

D_{ij} is the effect of the j^{th} dam mated to the i^{th} sire

and e_{ijk} is the residual effect.

Three measures of heritability can be obtained **(Falconer,** 1960): that from the sire component, $h_2S = 4\ S\ /$ hat from the dam component, $h_2\ D = 4\ D\ /$ and that from the sire-plus-dam components, $h_2S + D = 2\ (S+D)/$. The three heritability ratios are equal when S=**D** and can be estimated with various functions of the three mean squares in the analysis of variance model **(I).** An important assumption in the use of the full-sib family model for estimating heritability is that only additive genetic variance contributes to the covariance between family members **(Hill** and **Nicholas,** *1974).* Wolc *et al.* (2009b) recently proposed a sire-dam random regression framework for analysing fertility which accounts for all sources of variation, including age and simultaneously estimates parameters for male and female fertility.

A wide range of heritability estimates of fertility and hatchability has been reported in literature. Beaumont *et al*. (1997) reported heritability estimates of 0.09 and 0.31 for fertility from sire and dam respectively. The estimate for hatchability of fertile eggs were 0.05 and 0.15 respectively, when estimated from the sire or dam components. Wolc *et al*. (2009) reported heritability of fertility estimates to be low at all ages (9% for the female and 11% for the male). Sapp *et al*. (2004) reported heritability estimates ranging from 5.5% to 7.4%. *Heritabilities for duration of fertility traits in Brown Tsaiya female ducks reported by Tai et al. (1994) ranged from 0.29 to 0.38 while Kosba et al. (1983) reported a range of 0.14 to 0.93 in two Alexander lines and Fayoumi chickens.* Chao and Lee (2001) reported heritability of fertility percentage of 0.459 0.297 and 0.2340.227 in experiments I and II, respectively.

*Most heritability estimates from dam variance component are usually higher than sire or sire plus dam estimates. (*Singh *et al.,* 1991; *Beaumont et al., 1997).* The higher value of the dam component is most probably due to the existence of dominance and maternal effects, (Crawford, 1990); Roff, 2008). It can also be due to additive sex-linked genetic effects (Becker, 1984). Poivey *et al*, (2001) reported higher heritability estimates from dam than estimates from sire + dam in ducks.

This study was designed to estimate genetic parameters of fertility and hatchability and associated traits in two strains of Rhode Island Red Chickens using the full-sib and maternal half-sib analyses.

Materials and Methods

Source of Experimental Materials

The experiment was carried out at the Poultry Breeding Unit of National Animal Production Research Institute (NAPRI), Shika, Zaria, Nigeria. NAPRI is geographically located between latitude 11^0 and 12^0N and longitude 7^0 and 8^0E at an altitude of 640 m above sea level. This area is vegetationally in the Northern Guinea Savanna zone with an average annual precipitation of 1100 mm. Rainfall starts in late April or sometimes early May, reaches peak between June and September and lasts till October. The wettest month, August has a minimum temperature of 27.5°C, whereas the mean maximum temperature during the hottest month, April was 35.2°C.

Two strains of Rhode Island Chickens (Red and White) belonging to the breeding unit of poultry research programme of the Institute were used for the study. The birds were obtained from the selected lines (male and female lines) and are designated as Strain A and B respectively. Strain A has gold plumage while Strain B has silver plumage.

About 252 hens and 28 cocks of Rhode Island Red and Rhode Island White (RIR and RIW) each with record of performance were selected. They were transferred from battery cages to deep litter pen houses where they were grouped in a ratio of 1 cock to 9 hens in each pen. Hens used for this study were aged 42-50 weeks. The hens were trap nested with eggs set for incubation every week. Eggs were identified by **sire and dam** number before incubation. For the male, the total number of eggs set was the sum of all settable eggs laid by all the hens in the pen within the given period, while for the female, number of eggs set related only to the total number of settable eggs laid by the individual female within the period.

Eggs were candled on the 18th day of incubation to record the number of infertile eggs. On the day of hatching, all chicks were wing-banded and pedigreed by sire and dam. The chicks were also vaccinated against Newcastle disease using intraocular (I/o) Newcastle disease vaccine and Marek's vaccine against Marek's disease.

Data analysis

The number of fertile eggs set and number of chicks hatched were recorded for both strains A and B. A total of 2115 and 2050 fertility and hatchability records were available for strain A and B respectively. The following traits were measured:

i Number of egg set
ii Number of fertile eggs
iii Hatchability of all eggs set (PCH)
iv Hatchability of fertile eggs (PCHBLY)

Percent fertility, percent hatch, and percent hatchability were calculated as follows:

Percent fertility =

$$\frac{\text{Total number of fertile eggs}}{\text{Total number of eggs set}} \times 100$$

Percent hatch =

$$\frac{\text{Total number of chicks hatched}}{\text{Total number of eggs set}} \times 100$$

Percent hatchability =

$$\frac{\text{Total number of chicks hatched}}{\text{Total number of fertile eggs}} \times 100$$

Mixed model least squares and maximum likelihood computer program by Harvey (1985) was used for the analysis. Genetic parameters were estimated using (a) full-sib analysis whereby the variance components were partitioned into those due to Sire + Dam or environment. In this design, the statistical model used was:

$$Y_{ijk} = \mu + S_i + D_j + e_{ijk}$$

Where

Y_{ijk} = the record of the kth Progeny of ijh Dam mated to the ith Sire

μ = the common mean

S_i = the effect of the ith Sire

Dj=Effect of the jth Dam

e_{ij} = The uncontrolled environmental and genetic deviation attribute to the individuals. Error terms were random, normal and independent with expectation equal to zero.

(b) Maternal half sib whereby the variance components were partitioned into those due to Dam or environment. In this design, the statistical model used was of the form:

$$Y_{ijk} = \mu + D_i + e_{ij}$$

Where y_{ij} = the record of the ijh Dam

μ = the common mean

D_i = the effect of the ith Dam

e_{ij} = The uncontrolled environmental and genetic deviation attribute to the individuals.

All error terms were random, normal and independent with expectation equal to zero.

Results and discussion

Table 1 shows means and standard errors of fertility and hatchability traits in the two strains

Table 1. Least square means and standard errors of means of fertility and hatchability traits of Rhode Island chickens

Traits	Strain A	Strain B
EGGSET	4.26±0.09	3.92±0.10
NFERT	3.63±0.09	3.33±0.12
NHATCH	2.74±0.09	2.39±0.10
PFERTLT	84.48±1.32	83.94±1.73
PHATCH	62.77±1.75	59.52±1.75
PHTCHBLY	70.18±1.66	65.51±1.83

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY =Percentage of hatched chicks from fertile eggs

of Rhode Island chickens. The values of NFERT, NHATCH and PHATCHBL obtained in the study were lower than the range reported in literature. Szwaczkowski *et al.* (2003) reported 87.1% fertility and 75.5% of eggs hatched.

Malago and **Baitilwake (2009) reported** 91.1±4.42 % for fertility and 64.0±2.16% for hatchability in RIR. Values obtained for EGGSET, NFERT, NHATCH, PHATCH and PHATCHBL were all higher in strain A than in strain B. Strain differences in fertility and hatchability traits have been reported (Mishra *et al.,* 1990; Singh and Belsare ,1991).

Moderate to high heritability estimates obtained for percentage fertility have been reported elsewhere. Chao and Lee (2001) reported heritability of fertility percentage of 0.459 0.297 in experiment I and 0.2340.227 in experiment II. Kosba *et al.* (1983) reported that heritability estimates of the duration of fertility in Alexander high line was 0.44 and 0.93 in Fayoumi chickens. *Tai et al. (1994) reported a range of 0.29 to 0.38 heritability estimate of duration of fertility in Brown Tsaiya ducks.* High heritability is a reflection of additive genetic variability in the birds.

Table 2. Heritability Estimates of fertility and hatchability traits in Rhode Island chickens

	Strain A		Strain B	
Traits	Full sib	Maternal half sib	Full sib	Maternal half sib
EGGSET	0.43±0.07	0.87±0.13	0.39±0.07	0.55±0.12
NFERT	0.48±0.07	0.96±0.13	0.48±0.07	0.67±0.13
NHATCH	0.46±0.07	0.93±0.13	0.40±0.07	0.74±0.13
PFERTLTY	0.38±0.07	0.76±0.12	0.47±0.07	0.81±0.13
PHATC H	0.40±0.07	0.40±0.12	0.30±0.06	0.59±0.12
PHTCHBLY	0.29±0.06	0.58±0.11	0.24±0.06	0.49±0.12

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY=Percentage of hatched chicks from fertile eggs

Table 3: Genotypic correlation (below) and phenotypic correlations (above) diagonal of Strain A (Sire+Dam variance)

	EGGSET	NFERT	NHATCH	PFERTLTY	PHATCH	P HATCH BLY
EGGSET		0.75	0.58	0.06	0.11	0.16
NFERT	0.71±0.07		0.75	0.62	0.41	0.29
NHATCH	0.66±0.08	0.86±0.04		0.45	0.79	0.72
PFERTLTY	0.14±0.05	0.65±0.09	0.60±0.10		0.54	0.33
PHATCH	0.34±0.14	0.66±0.10	0.85±0.04	0.65±0.09		0.87
PHATCHBLY	0.36±0.14	0.66±0.10	0.85±0.05	0.63±0.11	0.93±0.02	

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY=Percentage of hatched chicks from fertile eggs

Table 4: Genotypic Correlation (below) and phenotypic correlations (above) diagonal of Strain B (Sire + Dam variance)

	EGGSET	NFERT	NHATCH	P FERTLTY	PHATCH	P HATCH BLY
EGGSET		0.84	0.63	0.10	0.09	0.14
NFERT	0.84±0.05		0.78	0.57	0.37	0.28
NHATCH	0.69±0.09	0.93±0.03		0.46	0.74	0.69
PFERTLTY	0.30±0.14	0.76±0.07	0.76±0.08		0.59	0.40
PHATCH	0.26±0.16	0.67±0.11	0.85±0.05	0.86±0.06		0.88
PHATCHBLY	0.28±0.17	0.69±0.12	0.83±0.07	0.88±0.08	0.99±0.02	

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY=Percentage of hatched chicks from fertile eggs

Table 5: Genotypic Correlation (below) diagonal and phenotypic correlations (above) diagonal of Strain A (Maternal Half sib variance)

	EGGSET	NFERT	NHATCH	PFERTLTY	PHATCH	P HATCH BLY
EGGSET		0.75	0.58	0.06	0.11	0.16
NFERT	0.75±0.06		0.75	0.62	0.41	0.29
NHATCH	0.67±0.08	0.90±0.04		0.45	0.79	0.72
PFERTLTY	0.09±0.15	0.71±0.08	0.63±0.10		0.54	0.33
PHATCH	0.29±0.14	0.66±0.09	0.85±0.04	0.71±0.09		0.87
PHATCHBLY	0.31±0.15	0.69±0.11	0.85±0.05	0.74±0.10	0.99±0.02	

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY=Percentage of hatched chicks from fertile eggs

The maternal half-sib estimates were higher than the estimates obtained from full-sibs. Poivey *et al*. (2001) reported higher heritability estimates from dam than estimates from sire + dam in ducks. Beaumont *et al.* (1997) reported higher heritability estimate of fertility from dam variance (0.31) components than from sire variance (0.09).

Table 6: Genotypic correlation (below) diagonal and phenotypic correlations (above) diagonal of Strain B (Maternal Half sib variance)

	EGGSET	NFERT	NHATCH	PFERTLTY	PHATCH	P HATCH \BLY
EGGSET		0.84	0.63	0.10	0.09	0.14
NFERT	0.79±0.07		0.78	0.57	0.37	0.28
NHATCH	0.65±0.11	0.92±0.05		0.46	0.74	0.69
PFERTLTY	0.27±0.18	0.80±0.09	0.76±0.10		0.59	0.40
PHATCH	0.25±0.20	0.71±0.13	0.90±0.06	0.87±0.08		0.88
PHATCHBLY	0.25±0.21	0.73±0.15	0.86±0.08	0.91±0.11	1.04±0.02	

EGGSET=Number of egg set, NFERT=Number of fertile eggs, NHATCH=Number of hatched chicks, PFERT=Percentage of fertile eggs, PHATCH=Percentage of hatched chicks from all eggs set, PHTCHBLY=Percentage of hatched chicks from fertile eggs.

Genetic parameter of fertility and heritability

Genetic correlations (Tables 3-6) were positive and ranged from low to high. However, the correlations between EGGSET with PFERT, PHATCH and PHATCHBLY in both strains either from dam or sire+dam variances were low. Essentially, the correlation between PHATCH and PHATCHBLY were high in all\
cases (=0.93). A high correlation between PHATCH and PHATCHBLY observed in this study agrees with the report of Poivey *et al. (*2001). Breeder flocks found to have high fertility are also thought to have high hatchability of fertile eggs. This assumption is supported by work of Cooper and Rowell **(1958),** McDaniel ***et al. (1981),*** and McIntyre ***et al.*** **(1986). Eslick and Mcdaniel (1992) had reported increase in total hatchability and hatchability of fertile eggs with increase in fertility percentage though with increase in spermatozoa concentration.** Tabatabaei *et al*. (2009) also reported significant positive correlation between fertility and hatch of fertile eggs. High genetic correlation reveals common genes acting additively.

Phenotypic correlations were also positive and ranged from medium to high in most cases. However, phenotypic correlations between EGGSET and PFERT in strain A either estimated from dam or sire+dam variance were low.

In conclusion, the medium to high heritability estimates obtained in this study indicate that the traits can be improved through selection. Moreover, the higher values from maternal half sib analysis reflect the maternal effect on these traits. The full-sib analysis for estimating heritability will be preferred since it is assumed that only additive genetic variance contributes to the covariance between family members.

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