Asian Australas. J. Biosci. Biotechnol. 2017, 2 (1), 37-44

Asian-Australasian Journal of Bioscience and Biotechnology
ISSN 2414-1283 (Print) 2414-6293 (Online)
www.ebupress.com/journal/aajbb

Article

Conservation and improvement of native chicken: performance of fourth generation

S. Faruque[1], A.K.F.H. Bhuiyan[2], Md. Yousuf Ali[3*], Z.F. Joy[4] and M.A. Rashid[1]

[1]Poultry Production Research Division, Bangladesh Livestock Research Institute, Savar, Dhaka-1341, Bangladesh
[2]Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[3]Bangladesh Livestock Research Institute, Regional Station, Baghabari, Shahjadpur, Sirajgonj-6770, Bangladesh
[4]Department of Genetic Engineering and Biotechnology, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

*Corresponding author: Md. Yousuf Ali, Bangladesh Livestock Research Institute, Baghabari Regional Station, Shahjadpur, Sirajgonj, Bangladesh. Phone: +8801717354092; E-mail: 113yousuf.bau@gmail.com, myousuf@blri.gov.bd

Received: 28 February 2017/Accepted: 23 April 2017/ Published: 30 April 2017

Abstract: Study was conducted at Bangladesh Livestock Research Institute, Savar, Dhaka with the objectives (i) to assess the performances of three Indigenous Chicken genotypes under intensive management, (ii) to select parental birds (males and females) and breed them in an assortative design for the production of fourth generation birds, and (iii) to estimate realized responses to selection to improve 3 Indigenous Chicken genotypes. A total of 1050-day-old chicks comprising of 3 types of chicken namely Naked Neck (NN), Hilly (H) and Non-descript Deshi (ND) were hatched in one batch for this study. In fourth generation (G_4), selection was practiced at 40-week of age on the basis of an index comprising the parameters of age at first egg (AFE), body weight (BW), egg production (EP) and egg weight (EW). Improvement target of egg weight was to increase by 1g, egg production rate was to increase by 2 % per generation. The data were analyzed by factorial arrangement in a CRD by General Linear Model (GLM) Univariate Procedure in SPSS Computer Program. Day old chick weight was significantly ($p<0.001$) highest in H (32.73±0.60 g). Significant ($p<0.001$) body weight differences among the genotypes were observed at 4^{th} , 8^{th} and 12^{th} weeks of age , with the highest body weight observed for H genotype (252.66±2.05, 674.68±6.41 and 1193.74±36.34g) than other two genotypes in all stages of age. H genotype (4.05 %) had non-significantly ($\chi^2 = 0.775$; $p > 0.05$) higher chick mortality than ND (3.10 %) and NN (2.92 %) genotypes at 0-8 weeks of age. The egg production up to 280 days was expected to increase by 3.34% for ND, 4.25% for H and 1.93% for NN, respectively. From the values obtained it was obvious that selection was effective in improving the percentage of egg production in three genotypes of chicken. The realized responses in terms of changes in breeding values in egg production and egg weight over generations were 0.722% and 5.349g, respectively. The negative genetic changes in age at first egg (-0.531 days) was in the expected direction. The realized response in age at first egg was found to decrease 0.531 days over two generations of selection. The realized response in the body weight at 40 weeks of age was found to be -0.001g due to selection over three generations. However, the results indicated that the genetic improvement for egg production in Indigenous Chicken will be effective through selection and breeding program. It may be concluded that the economic traits of Indigenous chicken could be improved in future generations through proper selection and planned mating.

Keywords: native chicken; performance; genotype; generation

1. Introduction

Agriculture is one of the drivers of growth of Bangladesh economy. The contribution of agriculture sector to GDP stood at 16.33 percent in FY 2013-14. Food security of the vast population of Bangladesh is directly linked with agriculture. Quddus (2000) found that considering the current situation of agriculture such as high population density, drought, floods and other natural calamities, scarcity of arable land, poor literacy and rural poverty etc., the livestock sub-sector is providing meaningful contribution to the socio-economic development of Bangladesh. The livestock consisting of 23.2 million cattle, 1.4 million buffalo, 25.2 million goat, 3.1 million sheep and 293.2 million of poultry (BER, 2013) contributes about US$ 2309.0 million as animal farming GDP sharing 18.6%, 56.3%, 19.8%, 2.68% and 2.64%, respectively by dairy, meat, egg, hides & skin and others (BBS, 2012). The livestock GDP has been growing @3.54% annually, and within decade time annual milk, meat, egg production will be increased by 42.5%, 142.3% and 106.9% respectively. It has been reported that commercial and family poultry ratio in terms of egg production is almost equal (50:50) and that of meat production is 60:40 in Bangladesh (Bhuiyan, 2011). Free range scavenging poultry are mostly indigenous or native birds locally knows as "Deshi" reared by farmers in small numbers in their households following traditional management (Chowdhury, 2013). Indigenous Chickens of Bangladesh are categorized as Non-descriptive Deshi (ND), Naked Neck (NN), Hilly (H), Aseel (AS) and Jungle fowl (Bhuiyan *et al.,* 2005) in respect of the morphological variations as well as production performances. Bangladesh has a rich heritage of Indigenous chicken germplasm, which strongly supported decisive measures for conserving Indigenous genetic resources. According to Bett *et al.* (2014), an understanding of farming system characteristics and their benefits to Indigenous chicken production is essential in the development of a holistic breeding and conservation program in South and South East Asian countries including Bangladesh. Selection for egg and meat production in purebred Indigenous Chickens has been carried out in many places of the world and it is evident that considerable improvement is possible (Bhuiyan *et al.,* 2005). Therefore, in order to improve the productivity of Indigenous Chickens the present work was undertaken to fulfill the following objectives of i) to assess the performances of three indigenous chicken genotypes under intensive management ii) to select parental birds (males and females) and breed them in an assortative design for the production of fourth generation birds and iii) to estimate realized responses to selection to improve 3 indigenous chicken genotypes under intensive management.

2. Materials and Methods

2.1. Production of fourth generation (G_4)

The study was conducted at Bangladesh Livestock Research Institute, under Poultry Production Research Division, Savar, Dhaka, Bangladesh. A total of 1050 progeny (ND=477, H= 259 and NN= 314) were hatched in one batch for fourth generation (G_4**)**. Day-old chicks collected from the hatchery were weighed and leg banded individually.

2.2. Rearing and data collection of fourth generation (G_4)

All the chicks of three genotypes were transferred into the brooder, which were cleaned and disinfected earlier and 5% glucose solution was supplied for the first three days. One-week later leg bands were removed and wing bands were provided all the experimental birds. De-baking was performed after 10-12 days of age. Concentrate mixtures that contain 20.06% Crude Protein & 2908 Kcal ME/kg DM; 18.13% Crude Protein & 2904 Kcal ME/kg DM and 16.33% Crude Protein & 2845 Kcal ME/kg DM were provided twice daily in the morning and evening during brooding, growing and laying period, respectively. Cool clean drinking water was supplied all the times. Water also was provided *ad libitum* twice daily in the morning and evening. Feeder was cleaned twice in a week where drinker was cleaned every day. Refusals of the feed were measured everyday in the morning. All chicks were vaccinated as per schedule given by veterinarian. All productive and reproductive records are being kept.

2.3. Selection and mating plan of fourth generation (G_4)

The selection objectives of the study were to improve the egg production, egg weight and / or growth rate of indigenous chicken depending on the genotype of birds. Improvement target of egg weight is to increase by 1 g and improvement target of egg production rate is to increase by 2% per generation. The main target was the mean body weight in ND, H, NN chickens have to be gone up from the initial eight-week body weight of 342, 375, 331 g on an average 349g to 500 g at 8 week of age after 5 generations of selective breeding. In fourth generation (G_4), selection was practiced at 2 (two) stages of birds life, firstly at 8 weeks of age, selection was performed on the basis of breeding value for 8 weeks body weight. At 8 weeks of age, a total of 460 females

(ND=230, H= 115 and NN= 115) and 175 males (ND=85, H= 45 and NN= 45) were selected according to breeding value on the basis of 8 week's body weight. Secondly, at 40-week of age, selection was done using multi trait index selection and independent culling level. The selection Index was computed by the following equation:

Selection Index (I) = $b_1x_1 + b_2x_2 + \ldots\ldots\ldots\ldots + b_nx_n$

Where, $x_1, x_2, \ldots\ldots x_n$ represent the phenotypic value for the trait
$b_1, b_2, \ldots\ldots b_n$ denote the relative weight given to each of the trait

The total score was obtained from above calculation is a selection index. The individual with the higher total score was selected for breeding purposes. Both index selection and independent culling levels were used to select chicken. Culling level used was as follows:

Trait	Culling level
ASM	$X \leq AV+2SD$
BW	$AV-2SD \leq X \leq AV+2SD$
EW	$AV-SD \leq X \leq AV+SD$
EP	$AV \leq X$
Index	$AV \leq X$

A total of 40 males (ND=20, H= 10 and NN= 10) and 200 females (ND=100, H= 50 and NN= 50) were selected comprising the parameters of Age at first egg (days), Body weight (g) at 40 weeks of age, Egg production (%) (168-280 days) and Egg Weight (g) at 38 - 40 weeks of age.

2.4. Breeding design and experimental chicken

Name of genotype	Sex	No. of day old chicks	No. of growing chicks		No. of adult birds	No. of selected bird at 40 wks of age	
			8 wks	16 wks.		Selected	Spare
ND	Male	477	85	40	40	20	10
	Female		230	200	200	100	20
H	Male	259	45	20	20	10	5
	Female		115	100	100	50	10
NN	Male	314	45	20	20	10	5
	Female		115	100	100	50	10

A total of 20 males (ND=10, H= 5 and NN= 5) and 40 female birds (ND=20, H= 10 and NN= 10) were kept as spare birds. In flocks of all genotypes and generations, selected males and females were mated assortatively with a maximum male: female ratio of 1:5 using artificial insemination and mating among close relatives were avoided.

2.5. Mating design of the experiment

	Non-descript Deshi (♂) (ND)	Hilly (♂) (H)	Naked Neck (♂) (NN)
Non-descript Deshi (♀)	ND♂×ND♀		
Hilly (♀)		H♂×H♀	
Naked Neck (♀)			NN♂×NN♀

2.6. AI and collection of hatching eggs to produce next generation (G_5)

Selected males and females were mated using artificial insemination. Artificial Insemination was practiced twice in a week. Hatching eggs were collected up to 10 days.

2.7. Data recording

All productive and reproductive parameters were recorded for fourth generation (G_2). Records were kept on day-old weight (g), fortnightly individual body weight up to 8 weeks, monthly weight up to 20 weeks, daily egg production, and egg weight at 38-40 weeks of age, temperature and humidity, growth rate, feed intake and feed conversion ratio (FCR). Feed conversion ratio (FCR) was recorded for the whole period as total feed intake (kg)

per kg weight gain. Temperature and humidity were recorded four times a day; (06:00h, 12:00h, 18:00h and 24:00h).

2.8. Statistical analysis

All recorded data were analyzed by Generalized Linear Model (GLM) procedure using SPSS 11.5 for Windows (SPSS, 1998). For all statistical purposes the theory of Snedecor and Cochran (1989) were followed. The present data used in the study were from three different genotypes and the structures of data were unbalanced. The number of birds varied from class to class and subclass to subclass. Hence, it confirmed the characteristics of a non-orthogonal factorial experiment. To take this situation into account the data were analyzed by factorial arrangement in a CRD by General linear Model (GLM) Univariate Procedure in SPSS Computer Program.
The following general linear statistical model was used to analyze the different parameters:
$\mathbf{Y_{ij} = \mu + g_i + e_{ij}}$, where, Y_{ij} is the dependent variable of the experiment; μ is the overall mean; g_i is the effect of *ith* genotype (i=1-3); e_{ij} is the error term specific to each record.

2.9. Prediction of expected selection response

Expected selection response in three types of indigenous chicken for body weight at 8 weeks was estimated using the following equation (Falconer, 1981).

i) $R = h^2 \times S$

Where,
R = Expected response in mass selection
h^2 = heritability, h^2 for BW at 8 weeks of age
S = Selection differential

ii) $R = 1/2\ h^2 \times S_f$

Where,
R = Expected response
h^2 = heritability (h^2 of EP, EW, AFE and BW)
S_f = Selection differential for the selected females.

2.10. Estimation of realized selection response

For estimating the realized response from foundation stock (G_0) to generation 3 (G_3); 775, 775, 775 and 778 records were available on EP (40wk), EW (40wk), AFE and BWT (40wk), respectively. Though there were many approaches for estimating realized selection response, however, in the present study realized response was estimated by regressing the generation-wise mean breeding value of a trait on generation number. For breeding value estimation, PEST program (Groeneveld *et al.*, 1990) was used.

3. Results and Discussion

3.1. Body weight

The effect of genotype on body weight is presented in Table 1. Genotype had significant ($p<0.001$) effect on body weight in all stages of age. NN chicks had 9.53% lower day old weight than that of H chicks. The difference of day old weight between H (32.73g) and NN (29.61g) for indigenous chicks was only 3.12g. Faruque (2015) found that the average initial body weight of day old chicks (ND=28.8, H=29.2, NN=28.1g) differed ($p<0.001$) by genotype. Faruque *et al.* (2007) found the body weight at 8 weeks of age for ND, H and NN genotypes were 481.9, 449.0 and 476.0g, respectively which were much lower than the present observations. Khandoker (1993) observed that body weight of indigenous chickens at 4, 8, and 12 weeks of age averaged 76.3, 186.5 and 475.0g, respectively which were much lower than the present findings. Body weight is the direct reflection of growth and it influences the production and reproduction traits of birds. Generally, all the body parameters increased with age of the birds in each genotype.

3.2. Mortality

H genotype (4.05%) had non-significantly ($\chi^2 = 0.752$; $P > 0.05$) higher chick mortality than ND (3.10%) and NN (2.92%) at 0-8 weeks of age which is shown in Table 2. Mortality rate was slightly lower in Naked Neck than Deshi and Hilly chicken (Khatun *et al*., 2005). This finding is similar to our present finding. Better survivability was observed in NN genotype in this study. Mortality rates of indigenous chickens in brooding, growing and laying period were 0-2.0, 0-6.9 and 0-5.7%, respectively under intensive system of rearing

(Faruque *et al.,* 2007). Khan (2008) reported 70% mortality of indigenous chickens under free range management.

Table 1. Body weight of Indigenous Chicken up to 12 weeks of age.

Parameter	Genotype			Level of sig.
	ND (Mean±SE)	H (Mean±SE)	NN (Mean±SE)	
DOC weight (g)	30.39^{b}±0.44 (475)	32.73^{a}±0.60 (256)	29.61^{b}±0.53 (319)	p<0.001
4^{th} week weight (g)	231.02^{b}±1.5 (462)	252.66^{a}±2.05 (249)	212.42^{c}±1.85 (304)	p<0.001
8^{th} week weight (g)	570.95^{b}±4.58 (460)	674.68^{a}±6.41 (235)	545.23^{c}±5.61 (300)	p<0.001
12^{th} week weight (g)	942.59^{b}±26.03 (458)	1193.74^{a}±36.34 (233)	835.52^{c}±32.46 (297)	p<0.001

DOC= Day Old Chick; ND=Non-descript Deshi; H=Hilly; NN=Naked Neck; figures in the parentheses indicate the number of observations; least squares means without a common superscript along the row within a factor differed significantly (p<0.05).

Table 2. Effect of genotype on chick mortality (%) during 0-8 weeks of age.

Genotype	ND	H	NN	χ^2 (df=2)	P-Value
Mortality (%)	3.10	4.05	2.92	0.752	p >0.05

Table 3. Egg production of Indigenous Chicken up to 442 days of age.

Parameter	Genotype			Level of sig.
	ND (Mean±SE)	H (Mean±SE)	NN (Mean±SE)	
Egg production (no.)	137.60±4.86 (10)	136.90±4.63 (11)	142.00±5.12 (9)	NS

ND=Non-descript Deshi; H=Hilly; NN=Naked Neck; figures in the parentheses indicate the number of observations

Table 4. Reproductive performance of native chicken.

Parameter	Genotype			Level of sig.
	ND (Mean +SE)	H (Mean +SE)	NN (Mean +SE)	
Dead in germ (%)	1.35±.84 (88)	3.20±1.26 (49)	2.08±1.12 (49)	NS
Fertility (%)	88.60±2.03 (88)	84.73±2.72 (49)	81.93±2.69 (50)	NS
Dead in Shell (%)	1.96^{c}±1.19 (85)	14.99^{a}±1.58 (48)	10.69^{b}±1.55 (50)	p<0.001
Culled chick (%)	2.20^{b}±0.91 (85)	9.15^{a}±1.22 (48)	2.71^{b}±1.19 (50)	p<0.001
Hatchability (%)	83.04±1.82 (85)	75.55±2.43 (48)	80.47±2.38 (50)	NS

ND=Non-descript Deshi; H=Hilly; NN=Naked Neck; figures in the parentheses indicate the number of observations; least squares means without a common superscript along the row within a factor differed significantly (p<0.05).

Table 5. Expected response to selection for 280 days egg production (%).

Genotype	Before selection		After selection		Selection Differential (S)	Selection Intensity (i)	Phenotypic standard deviation (sd)	Heritability of the trait (h^2)	Expected response to selection (R)
	No.	Aver.	No.	Aver.					
ND	180	49.35	100	56.04	6.69	0.62	10.78	0.50±0.03	3.34
H	107	46.93	50	55.61	8.68	0.68	12.68	0.49±0.03	4.25
NN	93	51.42	50	56.93	5.51	0.67	8.20	0.35±0.01	1.93

ND=Non-descript Deshi; H=Hilly; NN=Naked Neck;

Table 6. Realized responses in egg production, egg weight, age at first egg and body weight at of indigenous chicken.

Trait	Generation	Average breeding value (BV)	Realized response per generation
Egg production (%) up to 280 days	G_0	-0.3583	0.722
	G_2	0.3638	
Egg weight (g) at 40 weeks	G_0	-2.6511	5.349
	G_2	2.6987	
Age at first egg (days)	G_0	0.2619	-0.531
	G_2	-0.2696	
Body weight at 40 weeks (g)	G_0	0.0025	-0.001
	G_2	-0.0023	
	G_3	-0.0010	

*****G_0 = Foundation generation; G_2 = Second generation; G_3= Third generation

3.3. Egg production

The effect of genotype on egg production is presented in Table 3. Four hundred forty two days (442 days) egg production was not influenced ($p>0.05$) by genotype. Among three genotypes, NN (142.00) was found better in terms of average number of eggs in certain periods than those of ND (137.60) and H (136.90). Yoshimura *et al.* (1997), Moreki and Mosupu (2003) reported that among all other indigenous chickens, the Naked Neck (NN) laid a significantly ($p<0.05$) higher number of eggs compared to the other genotypes including fizzle and normal feathered birds which is similar to current findings. Huque (1999) found annual egg production of selected NN, H and ND as 141, 101 and 121, respectively under intensive rearing.

3.4. Reproductive performance

Reproductive traits of indigenous chicken according to genotype are presented in Table 4. Percentages of dead in germ, fertility and hatchability were not affected ($p>0.05$) by genotype. But percentages of dead in shell and cull chick were affected ($p<0.001$) by genotype. Khatun *et al.* (2005) found 1.60±0.50 percent dead in germ and 12.24±2.14 percent dead in shell in indigenous chicken. Dead in germ may be less dependent on genotypes rather may be more influenced by management and environment. Such a result agrees with Khalil (1960) who stated that embryonic mortality in Fayoumi eggs were 6.1, 2.7 and 14% during 3 weeks of incubation due to seasonal variation. Dead in shell also had little relation with genotypes but more dependence of dead in shell to management and environment. This result agrees with Patil *et al.* (1979) and contradicts to Jull (1951). Patil *et al.* (1979) reported seasonal variation increased embryonic mortality (DS). Jull (1951) reported genetic constitution had some effect on embryonic mortality providing good feeding management and maintaining optimum condition. Fertility percentage in the current study ranged from 81.93 to 88.60 percent in different genotype. Islam *et al.* (1981) reported that the fertility of upgraded Indigenous Chicken was 83%, which was lower than that observed in the present study. Khatun *et al.* (2005) reported that the fertility was 94.86, 88.40 and 88.09%, respectively in ND, H and NN genotypes, which were higher than the present findings. The highest hatchability found in this study was in ND genotype (83.04%) and the lowest hatchability was found in H genotype (75.55%). Khatun *et al.* (2005) showed that the hatchability of fertile eggs ranges from 88.04 to 94.86% in different genotypes with an overall of 85.99 %, which was little bit higher than the present findings.

3.6. Expected response to selection

Table 5 shows the expected responses for egg production up to 280 days in fourth generation (G_4) of three genotypes of chicken. The egg production up to 280 days was expected to increase by 3.34, 4.25 and 1.93% for ND, H and NN genotypes, respectively.

The responses to selection for egg production up to 280 days for three genotypes of chicken were expected to increase and higher in H genotype than other two genotypes. From the values obtained it was obvious that selection was effective in improving the percentage of egg production in three genotypes of chicken. Singh *et al.* (2005) reported that the response in egg number of purebreds was expected to be positive 2.922, 0.209, 0.028, 0.037 in first four generations and -0.024 and -0.021 in G_5 and G_6 generations.

3.7. Realized response

The realized or observed response per generation of selection was estimated by regressing the mean breeding value of the trait on generation number which is presented in Table 6 for different traits of three genotypes of chicken. The realized responses in terms of changes in breeding values in egg production and egg weight over generations were 0.722% and 5.349g, respectively (Table 6). The negative genetic changes in age at first egg (-0.531 days) was in the expected direction. The realized response in age at first egg was found to decrease 0.531 days over two generations of selection. The realized response in the body weight at 40 weeks of age was found to be -0.001g due to selection over three generations (Table 6). Singh *et al.* (2005) reported that the realized responses in egg number of purebreds ranged from -16.14 to 11.66 over the six generations. Their findings are in agreement with the present finding though smaller in degree. However, the results indicated that the genetic improvement for egg production in Indigenous Chicken will be effective through selection and breeding program. The realized response per generation for egg weight at 40 weeks was 5.349g which was much higher than the result of Dev Roy *et al.* (1983) who found the realized response for egg weight 0.44g. These results imply that the genetic improvement for the trait is possible in three indigenous genotypes of chicken of Bangladesh. The negative genetic changes in age at first egg (-0.531 days) was in the desirable direction and in agreement with the findings of Marks (1981). Kumar and Singh (2009) reported realized response for this trait to be decreased by -0.19 days, for broiler dam line in their study which is less achievement than the achievement of this study. The results of this study suggested that the genetic improvement of age at first egg laid through reducing the number of days to attain first egg lay is possible applying selection and breeding. As a correlated response to selection for egg production, the realized response per generation in the body weight at 40 weeks was found to be -0.001g over two generations. Low and negative genetic correlation between body weight and egg production observed before concur well that selection for higher body weight may reduce number of eggs to some extent and coincides with the findings of Niknafs *et al*. (2012). Unexpected negative realized response in body weight may also be due to feed restriction of pullets during growing period.

4. Conclusions

Evaluation of the phenotypic performances of three genotypes of Indigenous Chicken indicated that Naked Neck chicken was good for egg production purposes and Hilly chicken for meat purposes. The findings of the present study provided results which clearly indicated an effectiveness of this selective breeding program in improving considered economic traits of Indigenous Chicken of Bangladesh. It is therefore suggested to continue such selection program to ensure conservation and sustainable development of Indigenous Chicken genetic resources of the country.

Conflict of interest

None to declare.

References

BBS, 2012. Bangladesh Bureau of Statistics. Statistical Year Book of Bangladesh, Statistics Division, Ministry of Planning, the Government of Bangladesh.

BER, 2013. Bangladesh Economic Review. Economic Adviser's Wing, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, p. 109.

Bett RC, AKFH Bhuiyan, MS Khan, GLLP Silva, LT Thuy, SC Sarker, MND Abeykoon, TTH Nguyen, S Sadef, E Kariuki, I Baltenweek, J Poole, O Mwai and MNM Ibrahim, 2014. Indigenous chicken production in the south and south east asia. Livestock Research for Rural Development 26(12). http:// www.lrrd.org/ lrrd26/ 12/bett26229.html

Bhuiyan AKFH, 2011. Implementation of National Livestock Development Policy (2007) and National Poultry Development Policy (2008): Impact on smallholder livestock rearers. Keynote paper presented at the South Asia Pro Poor Livestock Programme (SAPPLP), BRAC Center, Dhaka.

Bhuiyan AKFH, MSA Bhuiyan and GK Deb, 2005. Indigenous chicken genetic resources in Bangladesh: Current status and future outlook. Animal Genetic Resources Information's Bulletin, 36: 73-84.

Chowdhury SD, 2013. Family poultry production in Bangladesh: is it meaningful or aimless journey? Worlds Poult. Sci..**,** 69**:** 649-665.

Dev Roy AK, SC Mohapatra, BP Singh, RP Sharma and DC Johari, 1983. Relative efficiency of index selection for broiler weight. Indian J. Poult. Sci., 18: 52-56.

Falconer DS ,1981. Introduction to Quantitative Genetics. Second Edition. Chapter 11. Selection response and its prediction, pp. 171-177.

Faruque S, 2015. Selection for improvement of economic traits of indigenous chicken in Bangladesh. Ph.D. Thesis, submitted to the Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh.

Faruque S, NR Sarker, MN Islam and MSK Sarker, 2007. Performance of native chickens under intensive system. J. Bangladesh Agril. Univ., 5: 283-288.

Groeneveld E, M Kovac and T Wang, 1990. PEST, a general purpose BLUP package for multivariate prediction and estimation. Proceedings of the 4th World Congress on Genetics applied to Livestock Production, Edinburgh 23-27 July 1990. XIII: 488-491.

Huque QME, 1999. Poultry Research and Development in Bangladesh. Proceedings of the 1st Seminar and International Poultry show, April 24-26, IDB Bhaban, Sher-e- Bangla Nagar, Dhaka Bangladesh. : 70-80.

Islam ABMM, MM Huque and QMF Rahim, 1981. Reproductive performance of upgraded Indigenous Chicken. Poultry Adviser, 14: 32-37.

Jull MA,1951. The genetic constitution of the breeding stock have some effect on embryonic mortality. Poultry Husbandry, Third edition. Mcgraw Hill Book Company Inc. New York, Toronto, London, pp. 158-159.

Khalil AZ, 1960. Effect of crossing on fertility and hatchability of Fayoumi chicken. M.Sc. Thesis. University of Alexandria, Alexandria U.A.R. cited from Poult. Sci., 41: 1707-1712.

Khan AG, 2008. Indigenous breed, crossbreds and synthetic hybrids with modified genetic and economic profile for rural family and small scale poultry farming in India. World's Poult. Sci. J., 64: 405-415.

Khandoker MAMY, 1993. Performance of Indigenous (Deshi), Rhode Island Red (RIR) and Deshi × RIR chickens under farm condition. Master of Science in Poultry Science, thesis submitted to the Department of Poultry Science, Bangladesh Agricultural University, Mymensingh.

Khatun R, MS Islam, S Faruque, SA Azmal and MS Uddin, 2005. Study on the productive and reproductive performance of 3 native genotypes of chicken under intensive management. J. Bangladesh Agril. Univ., 3: 99-104.

Kumar S and RP Singh, 2009. Expected and realized response in various traits of broiler dam and sire lines. Indian J. Anim. Sci., 79: 1066-1068.

Marks HL,1981. Selection for egg mass in domestic fowl. 1. Response to selection. Poult. Sci., 60: 1115-22.

Moreki JC and PK Masupu, 2003. Country reported on local chicken production. J. Poult. Sci., 24: 407-420.

Niknafs S, A Nejati-Javaremi, H Mehrabani-Yeganeh and SA Fatemi, 2012. Estimation of genetic parameters for body weight and egg production traits in Mazandaran native chicken. Trop. Anim. Health Prod., 44: 1434-1443.

Patil NA, M Singh and IG Chavan, 1979. Effect of month and strain variation on embryonic mortality. Animal Breeding Abstract, 48: 393.

Quddus MA 2000. Socio-economic aspects of developing livestock and poultry resources in rural Bangladesh. The Journal of Rural Development, 30: 103-123.

Singh N, RP Singh andBS Malik, 2005. Expected and realized correlated responses in egg number of crossbreds and purebreds in egg type chicken. Proceedings of XXIII IPSACON. 2-4 February, 2005. Rajendranagar, Hyderabad, India.

Snedecor GW and WG Cochran, 1989. Statistical Methods, 8th Edition. The Iowa State University Press, Ames, IA, USA.

SPSS, 1998. SPSS Base 11.5 Application Guide, SPSS Inc., USA.

Yoshimura Y, A Basua, B Heryanto, H Ohira and W Zheng, 1997. Reproductive physiology in domestic animal as a basic Knowledge to improve poultry production in Asian countries. J. Agr. Sci., 41**:** 367-370.