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Conservation and Genetic Evaluation of Exotic Chicken Germplasms and Their Crossbreds Under Intensive Rearing in Bangladesh

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ABSTRACT

This study aimed to enhance the conservation and productivity of four purebred chicken lines (White Leghorn, WL; Rhode Island Red, RIR; White Rock, WR; and Barred Plymouth Rock, BPR), as well as their crossbreds with Desi chickens. For crossbreeding, two of the pure lines, BPR and RIR, were used to develop three crossbred combinations: Cross 1 (BPR × Desi), Cross 2 (Desi × RIR), and Cross 3 (RIR × Desi, reciprocal to Cross 2). A total of 4,000-day-old chicks were selected using a multi-trait index incorporating age at first egg (days), 40th week body weight (g), egg production rate measured between 168 and 280 days of age (%), and 40th week egg weight (g). Crossbreds were assessed for growth performance, reproductive traits, feed efficiency, and carcass characteristics. Selection in the pure lines achieved significant genetic gains, with a selection response of 2.81% for egg production in WR and 1.96 g for egg weight in WL, while maintaining high genetic diversity (effective population size, $N_e > 80$) and minimal inbreeding ($\Delta F = 0.006$). In crossbred evaluation, Cross 3 showed significantly higher ($P<0.05$) body weight (1352.8 g) and weight gain (1314.74 g) compared to Cross 1 (1302.5 g; 1265.19 g) and Cross 2 (1215.1 g; 1179.23 g) at 12 weeks of age. Feed intake was highest in Cross 3 (3447.25 g), with the best FCR (2.622 vs. 2.712 in Cross 1 and 2.642 in Cross 2). The superior performance of Cross 3 over its reciprocal cross (Cross 2) underscores the critical role of maternal or paternal line effects in crossbreeding outcomes. The findings suggest that conserving native genetic resources, combined with selective breeding, can significantly enhance productivity performance in tropical poultry farming.

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Introduction

The poultry sector is considered a crucial element of nutritional and economic security in tropical developing countries like Bangladesh, where over 85% of rural households are directly involved in small-scale chicken rearing (Sultana et al., 2012; Rahman et al., 2021). Poultry meat and eggs are the most affordable sources of animal protein, accounting for approximately 25% of total animal protein consumption, and poultry meat alone contributes 37% of the total meat supply in Bangladesh (Hamid et al., 2017). The native chicken breeds in Bangladesh exhibit higher disease resistance and adaptability to harsh climates (Barua et al., 1992; Das et al., 2008). However, these advantageous traits are often undervalued, as the inherent genetic constraints of native breeds limit their growth performance, reproductive capacity, and overall production efficiency (Pandey et al., 2018; Bidi et al., 2019).

Furthermore, the indigenous chicken typically attains sexual maturity at approximately six months of age, with a body weight ranging from 1.0 to 1.3 kg, and exhibits relatively low annual egg production, approximately 40–50 eggs (Bhuiyan et al., 2005). Consequently, farmers are required to maintain native birds for a minimum of six months before marketing, particularly when intended for meat production, which may affect production efficiency and economic returns (Ullengala et al., 2020). The productivity is significantly lower than that of commercial broiler and layer strains in terms of meat and egg production. To bridge the productivity gap, strategic genetic improvement while conserving valuable native traits has become a pressing priority.

The incorporation of exotic germplasms such as White Leghorn (WL), Rhode Island Red (RIR), White Rock (WR), and Black Australorp (BA) is an excellent method to increase productivity, as these breeds exhibit superior growth rates (reaching 1.5 kg in 6 weeks) and egg production (280–300 eggs/year) under optimal conditions (Khawaja et al., 2012a; Gheorghe et al., 2021; Werner et al., 2023; Pourhamidi et al., 2024). However, straightforward integration of exotic germplasms into tropical smallholder systems often fails due to low heat tolerance, higher feed costs, and disease susceptibility (Islam and Nishibori, 2009; Kang et al., 2021).

In such circumstances, the strategic crossbreeding of indigenous and exotic chickens represents a viable approach, aiming to combine complementary genetic backgrounds. The goal of such programs is to exploit hybrid vigor (heterosis), a phenomenon where crossbred offspring outperform the average of their purebred parents in traits such as growth rate, fertility, and overall fitness, thereby optimizing the overall performance of the resulting hybrids (Rizzi et al., 2013; Mwaisaka et al., 2020). However, due to the absence of comprehensive selection protocols, the progress of crossbreeding is often neglected. Effective genetic improvement of these parent lines requires simultaneous selection for multiple economically important traits. However, selecting for one trait (e.g., growth rate) can often lead to unintended negative consequences in others (e.g., egg production or fertility) due to antagonistic genetic correlations. To overcome this challenge and achieve balanced genetic gain, multi-trait selection indices, which weight key traits based on their economic importance and genetic parameters, are widely used in commercial breeding programs to increase chicken productivity (growth, egg production, and efficiency) (Chomchuen et al., 2022). However, previous studies in Bangladesh have historically focused on single traits, such as 8 or 16-week body weight for growth performance in Desi chickens (Faruque et al., 2017; Faruque et al., 2020; Sultana et al., 2021). This limited approach overlooks crucial factors of profitability, such as body weight gain, overall viability regarding morphological defects, and FCR, which account for up to 60-70% of production expenses (Thirumalaisamy et al., 2016).

Furthermore, both the growth performance and meat quality attributes of crossbred chickens, including pH, tenderness, and drip loss, remain inadequately characterized, despite their significant impact on consumer preferences and market outcomes. Simultaneously, the conservation of exotic genetic resources within tropical ecosystems presents long-term challenges, as small flock sizes and the absence of systematic selection increase the risk of inbreeding depression and loss of allelic diversity (Juiputta et al., 2025). Most of the exotic chicken germplasms existing in Bangladesh are primarily maintained by the Bangladesh Livestock Research Institute (BLRI), and there is limited published data on selection responses over generations. This gap impedes evidence-based breeding decisions and hinders the resources' ability to contribute to national productivity goals.

Therefore, this study addresses these gaps through a dual-pronged investigation: (1) quantifying genetic progress in four conserved exotic lines (WL, RIR, WR, and BPR) under a novel multi-trait selection index encompassing 40-week body weight, egg production rate, and egg weight; and (2) evaluating three crossbred combinations for growth performance, feed efficiency, and meat quality under intensive rearing.

Materials and Methods

Experiment 1: Conservation and genetic evaluation of exotic chicken germplasms

Experimental design

In Experiment 1, four exotic chicken lines, White Leghorn (WL), Rhode Island Red (RIR), White Rock (WR), and Barred Plymouth Rock (BPR), were chosen because they represent foundational, globally important lines with distinct selection histories. WL is a classic Mediterranean layer breed well known for high egg production, while RIR is a dual-purpose breed recognized for its brown eggs and resilience. WR and BPR are closely related meat-type breeds that form the genetic basis for modern broiler parent stock. Their diverse genetic backgrounds and specialized phenotypes make them ideal models for conservation and genetic improvement. The WL, RIR, WR, and BPR were obtained by the Poultry Production Research Division (PPRD) of the Bangladesh Livestock Research Institute (BLRI) for the selection and genetic improvement of pure lines. Birds were initially selected based on phenotypic characteristics and subsequently evaluated using a selection index to identify individuals with superior breeding values for continuation in the breeding program.

Experimental chick production from selected pedigree lines

A total of 4000 pedigree day-old chicks (1000 per line) were individually identified using a tag number. Selection of breeding birds was conducted at multiple growth periods: at 8 and 16 weeks of age, 100 males and 400 females were selected based on pedigree records, body weight, body weight gain, and overall viability and absence of morphological defects (Table 1). The final selection at 38 weeks involved choosing 50 males and 200 females based on the calculated selection index to produce the next generation. This 1:4 sex ratio was carefully selected to maximize both selection intensity and the maintenance of genetic diversity. The limited number of males (50) allows for strong selection pressure on sires, ensuring only the highest-index individuals contribute paternally. Meanwhile, the larger number of females (200) helps preserve a wider range of maternal lines, maintaining a higher effective population size (N_e) to reduce inbreeding and preserve genetic variation for long-term selections.

Housing, feeding, and management

Day-old chicks were leg-banded and individually weighed before being transferred to brooders. Initial care included the provision of a 5% glucose solution and vitamin supplementation in drinking water for the first six hours. The brooding temperature was maintained using 100-watt electric bulbs and adjusted as necessary. At 14 days, leg bands were removed, and wing bands were applied. Debeaking was performed between 10 and 12 days of age. Chicks were brooded and reared for up to 16 weeks in an open-sided, semi-gable roof house with a concrete floor. After 16 weeks, birds were housed individually in cages equipped with separate feeders and drinkers. The facility and cages were thoroughly cleaned and disinfected before the experiment began. Birds were provided with a concentrate feed formulated to contain 20.06% crude protein and 2908 kcal ME/kg dry matter. Feed was offered twice daily, with ad libitum access to clean drinking water. Vaccination followed standard veterinary schedules.

Lighting was managed with a photoperiod starting at 24 hours per day during brooding, reduced by one hour weekly, and maintained at 16 hours during the laying period, comprising 12 hours of natural sunlight plus 4 hours of artificial light.

Selection protocols

Selection was performed at 40 weeks of age using a selection index comprising four traits: age at first egg (days), body weight at 40 weeks (g), egg production rate (%) between 168–280 days, and egg weight at 40 weeks (g). The selection index (SI) was calculated as the weighted sum of these traits according to the following formula:

$$SI = \sum_{i=1}^{4} W_i \, x \, X_i$$

Where, W_i represents the weight assigned to each trait, and X_i is the phenotypic value. Individuals with the highest selection index (SI) scores were chosen for breeding. Both index selection and independent culling levels were utilized to optimize genetic gain while managing inbreeding.

Mating design

Males and females were selected and mated in a ratio of 1 male to 5 females. To ensure precise implementation of this design and guarantee accurate pedigree tracking, artificial insemination was employed. To minimize inbreeding, a rotational mating scheme was implemented whereby sires were mated with hens descended from different sires.

Prediction of expected selection response

Expected genetic responses for four traits: egg production (EP), egg weight (EW), body weight (BW), and age at sexual maturity (ASM) were calculated according to Falconer (1981) using the formula:

$R = h^2 \times S_f$

Where R is the expected response to selection, h^2 is the heritability of the trait (EP, EW, ASM, and BW), and S_f is the selection differential for the dam for the respective trait.

Determination of effective population size and rate of inbreeding

The effective population size (N_e) was estimated as

$$N_e = \frac{(4 \times N_m \times N_f)}{N_m + N_f}$$

Where N_m and N_f are the number of breeding males and females, respectively (Wright, 1933; Wright, 1939; Wang et al., 2016).

The rate of inbreeding (ΔF) per generation was calculated using the formula:

$$\Delta F = \frac{1}{(2N_e)}$$

Where N_e is the effective population size.

Experiment 2: Evaluation of Crossbred Chicken Growth Performance

Parental lines and crossbreeding design

The present study utilized a crossbreeding approach to assess the potential for enhancing meat production by introducing genes from a resilient, indigenous breed into improved pure lines. The experiment was specifically designed to assess growth performance and carcass traits.

The Desi chicken used was an improved non-descriptive Desi line maintained at the Poultry Research Farm, Bangladesh Livestock Research Institute (BLRI). This population has been under a long-term selective breeding program for improved growth and egg production traits while retaining adaptive characteristics. The Desi birds (cocks and hens) used as parents were aged between 32 and 36 weeks at the time of artificial insemination.

Table 1. Population Dynamics of Different Pure Lines at Various Growth Stages and Selected Breeding Birds

Pure Lines	Sex	No. of day-old chick	No. of growing chicken		No. of adult chicken	No. of selected bird
			8 wk.	16 wk.		
WL	Male	500	150	100	100	17
	Female	500	450	400	400	85
RIR	Male	500	100	100	100	17
	Female	500	450	400	400	85
WR	Male	500	100	100	100	17
	Female	500	450	400	400	85
BPR	Male	500	100	100	100	17
	Female	500	450	400	400	85

WR: White Leghorn; RIR: Rhode Island Red; WR: White Rock; BPR: Barred Plymouth Rock

(a) Cross 1 (b) Cross 2 (c) Cross 3

Figure 1. The Three Crossbreds: (a) Cross 1 (BPR × Desi), (b) Cross 2 (Desi × RIR), and (c) Cross 3 (RIR × Desi)

Table 2. Composition of experimental diet

Ingredients (kg)	Starter (0-21 days)	Grower (22-35 days)	Finisher (36-56 days)
Maize	52.10	55.10	59.90
Protein Concentrate	9.50	5.50	7.30
Rice Polish	8.00	8.00	8.80
Soybean meal	28.00	28.00	19.80
Di Cal Phosphate	1.00	2.00	1.50
Vit-Mineral Premix	0.25	0.25	0.25
Salt	0.50	0.50	0.5
Soybean Oil	0.50	0.50	2.00
Lysine	0.25	0.25	0.10
Methionine	0.15	0.15	0.10
Total	100.00	100.00	100.00
Calculated composition			
ME (Kcal/Kg)	3050	3100	3200
CP %	22	21	19
CF%	3.5	3.5	4.0
EE %	4-5	5-6	6-8
Ca %	1.05	1.0	0.95
P %	0.50	0.46	0.43
Lysine %	1.25	1.20	1.07
Methionine %	0.50	0.46	0.43

Contain per kg: Vitamin A, 12,000 IU; Vitamin D3, 5000 IU; Vitamin E, 50 mg; Vitamin K3, 3 mg; Vitamin B1, 2mg; Vitamin B2, 6 mg; Vitamin B6, 4 mg; Vitamin B12, 0.025 mg; biotin, 0.15 mg; pantothenic acid, 20 mg; folic acid, 2 mg; nicotinic acid, 7.0 mg; Fe, 66.72 mg; Cu, 41.70 mg; I, 0.834 mg; Se, 0.25 mg. ME: Metabolizable Energy; CP: Crude Protein; CF: Crude Fiber; EE: Ether Extract; Ca: Calcium; P: Phosphorus.

Table 3. Vaccination schedule of crossbred chicken

Age (day)	Vaccine Name	Trade Name	Dose	Route
5-6	IB+ND (Live)	MA5+Clone30	One drop	Ocular
9-12	IBD	D-78	One drop	Ocular
16-18	IBD	D-78	One drop	Ocular
21-23	IB+ND (Live)	MA5+Clone30	One drop	Ocular
40-42	ND (Live)	MA5+Clone30	One drop	Ocular

IB+ND: Infectious Bronchitis + Newcastle Disease; IBD: Infectious Bursal Disease.

The Rhode Island Red (RIR) and Barred Plymouth Rock (BPR) were selected as the improved pure lines for crossbreeding due to their superior growth rates and meat-yielding characteristics compared to the Desi breed. The specialized layer breed, White Leghorn (WL), was excluded as it is not a relevant contributor to meat production objectives. White Rock (WR), although a meat breed, may have been left out to focus on comparing two well-known dual-purpose breeds due to limited resources. This design resulted in three crossbred groups:

- Cross 1: BPR ♂ × Desi ♀
- Cross 2: Desi ♂ × RIR ♀
- Cross 3: RIR ♂ × Desi ♀
-

Figure 1 represents the pictorial view of three crossbred chickens. The reciprocal crosses with RIR (Cross 2 and Cross 3) were created to assess the influence of maternal or paternal effects on growth and carcass traits.

Experimental bird, design, and management

A total of 900-day-old crossbred chicks, Cross 1, Cross 2, and Cross 3, used pure line (300 chicks in each cross), were reared under farm conditions without prior sexing. The birds of the three crossbreds were randomly assigned to 30 pens per cross, each containing 10 chicks.

All parental lines and crossbred progeny were managed under the same standard conditions, which included a deep-litter housing system. The ambient temperature was kept at 33°C during the first week and then gradually reduced by 2–3°C each week until it stabilized at 22°C for the remainder of the experiment.

The rearing period was divided into three phases: starter (1–21 days), grower (22–35 days), and finisher (36–56 days). The birds had unrestricted access to water and were fed specific diets formulated for each phase, meeting NRC requirements (Table 2). Vaccination was performed according to the schedule described in Table 3. All other management practices adhered to the guidelines of Hassan et al. (2018).

Growth Performance Measurement

Weekly body weight measurements were taken for each pen to calculate the average body weight per pen and weight gain. The weekly feed intake for each pen was recorded, and the FCR was calculated as follows:

FCR=Weekly Feed Intake (g)/Weekly Body Weight Gain (g)

Feed intake data were normalized per bird by dividing the total feed consumed in each week by the number of birds remaining at the end of the period in the pen that week.

Carcass Evaluation

At the end of the experiment, five birds per pen close to the pen's average body weight were selected for carcass evaluation. Birds were individually weighed, slaughtered, and bled for two minutes. Body weight, bled weight, plucked weight, carcass weight, and eviscerated weight were recorded. Gastrointestinal tracts were removed, and the weights of the head, shank, viscera, heart, liver, and gizzard were documented. Abdominal fat was carefully excised and weighed separately.

Statistical analysis

Data were analyzed using the Generalized Linear Model (GLM) procedure of SPSS (version 11.5) for Windows. The statistical methodology followed the principles outlined by Snedecor and Cochran (1989). Statistical significance was set at P < 0.05 for all analyses.

Results

Experiment 1: Conservation and genetic evaluation of exotic chicken germplasms

Selection trait performance

The selection parameters for four pure-line chicken genotypes at the 20th generation (G20) are summarized in Table 4. The traits analyzed include age of sexual maturity (ASM, days), egg weight (EW), body weight (BW), and egg production (EP). The comparative evaluation of four pure chicken lines revealed statistically significant variation (P < 0.001) in key performance metrics. WL exhibited the highest EW (63.77 ± 8.61 g) and EP% (82.40 ± 5.99%) but the lowest BW (1422.14 ± 139.83 g). Conversely, RIR recorded the highest BW (1955.39 ± 197.85 g) and the lowest EW (57.80 ± 4.67 g). WR demonstrated the earliest ASM (137.97 ± 5.92 days), whilst BPR displayed the latest ASM (159.74 ± 6.19 days) and the lowest EP% (65.14 ± 19.59%).

Selection differential and response trends

The selection differential for EP (%) was investigated in WR and was found to be the lowest in RIR. Whereas the higher selection differential value for EW was found in WL and, similarly, the lowest in RIR. The WR shows a higher selection differential value for ASM than other breeds. However, the highest negative selection differential value was observed in BPR for BW. The WL exhibits the highest selection intensity in terms of EP% and EW compared to other purebreds. The WR line exhibited the highest selection response for EP% (R=2.81). Moderate selection response was investigated in BPR (R=2.39) and WL (R=1.88) for the same trait. However, the RIR showed the lowest selection response (R=1.14) for EP%. While considering the EW trait, the highest selection response (R=1.96) was found in WL, followed by WR and BPR, respectively. Similarly, the RIR line demonstrated the lowest section response (R=0.55) for EW.

Effective population size & inbreeding

Table 5 presents the effective population sizes (*Ne*) and inbreeding rates (ΔF) for the four genotypes at generation 20. Effective population sizes were relatively high (80–83), indicating effective genetic diversity management across sire and dam contributions. Correspondingly, the rates of inbreeding were minimal (ΔF = 0.006) for all four pure lines (WL, RIR, WR, and BPR), signifying low inbreeding depression risks.

Table 4. Selection parameters of four pure lines in 20th generation (G_{20})

Pure lines	Selection criteria	Mean±SD	h^2	(S)	(i)	(R)
White Leghorn (186)	ASM (d)	149.17^b±6.33	0.4	1.68	0.27	0.67
	EW (g)	63.77^a±8.61	0.5	3.92	0.46	1.96
	BW (g)	1422.14^d±139.83	0.5	-6.55	-0.05	-3.27
	EP%	82.40^a±5.99	0.15	12.53	2.09	1.88
Rhode Island Red (186)	ASM (d)	144.76^c±10.33	0.4	2.50	0.24	1.00
	EW (g)	57.80^b±4.67	0.5	1.08	0.23	0.54
	BW (g)	1955.39^a±197.85	0.5	-15.55	-0.08	-7.77
	EP%	73.78^b±12.53	0.15	7.60	0.61	1.14
White Rock (134)	ASM (d)	137.97^d±5.92	0.4	3.11	0.53	1.24
	EW (g)	58.59^c±4.03	0.5	1.73	0.43	0.86
	BW (g)	1675.44^c±147.15	0.5	-15.08	-0.10	-7.54
	EP%	72.74^b±18.08	0.15	18.76	1.04	2.81
Barred Plymouth Rock (164)	ASM (d)	159.74^a±6.19	0.4	-2.13	-0.34	-0.85
	EW (g)	59.05^b±4.20	0.5	1.51	0.36	0.75
	BW (g)	1695.70^b±168.20	0.5	-34.98	-0.21	-17.49
	EP%	65.14^c±19.59	0.15	15.92	0.81	2.39
P-value	ASM (d)	<0.001	-	-	-	-
	EW (g)	<0.001	-	-	-	-
	BW (g)	<0.001	-	-	-	-
	EP%	<0.001	-	-	-	-

The numbers in parentheses represent the sample size; SD: Standard deviation; h^2: Heritability; S: Selection Differential; R: Selection response; i: Selection Intensity; ASM: Age at Sexual Maturity; BW: Body Weight; EP: Egg Production; EW: Egg Weight.

Table 5. Rate of Inbreeding of four pure lines in 20th generation (G_{20})

Pure lines	Sire	Dam	Effective population size (N_e)	Rate of inbreeding (ΔF)
WL	25	125	83.33	0.006
WR	25	125	83.33	0.006
RIR	25	125	83.33	0.006
BPR	24	120	80.00	0.006

WL: White Leghorn; WR: White Rock; RIR: Rhode Island Red; BPR: Barred Plymouth Rock

Table 6. Performance of different cross-bred chickens (0-12 wk. of age)

Parameters	Crossbred chicken			P-value
	Cross 1	Cross 2	Cross 3	
DOC wt. (g/b)	37.51[ab]±3.43	35.86[b]±2.64	38.06[a]±2.71	0.013
Body weight at 12wk. (g/b)	1302.50[ab]±73.51	1215.1[b]±94.57	1352.80[a]±66.57	0.033
Weight gain (g/b)	1265.19[ab]±71.51	1179.23[b]±67.36	1314.74[a]±63.58	0.032
FCR	2.712±0.453	2.642±0.562	2.622±0.641	0.150

[a,b,c] :Mean values within a column followed by the same letter are not significantly different (P > 0.05)

Table 7. Live Weight, Carcass and Component Weights, and Dressing Percentages of Three Crossbred Chickens

Parameters	Crossbred chicken			P-value
	Cross 1	Cross 2	Cross 3	
Live body wt. (g)	1302.5[ab]±73.51	1215.1[b]±94.57	1352.8[a]±66.57	0.032
Bled wt.(g)	1253.5[ab]±67.21	1171.7[b]±87.17	1293.9[a]±67.58	0.031
Carcass wt. (g)	687.6[a]±56.33	644[b]±52.67	709.1[a]±41.01	0.043
Edible carcass wt.(g)	970.59[a]±65.47	854.7[b]±66.09	949.29[a]±52.35	0.029
Breast wt. (g)	93.1±7.33	91.8±9.74	99.5±5.24	0.513
Thigh wt. (g)	131.8±10.10	124.4±13.17	136.5±5.72	0.571
Wing wt. (g)	76.5±7.31	71.6±6.46	80±5.60	0.469
Drum wt. (g)	124.4±7.92	119±12.14	133±10.09	0.623
Abdominal fat wt.(g)	5.1±2.66	7.7±2.33	4.2±1.30	0.238
Dressing %	52.59±1.52	53.04±0.60	52.36±0.68	0.892
Edible dressing (%)	74.31±1.19	70.36±0.49	70.08±0.80	0.348

[a,b,c]: Mean values within a column followed by the same letter are not significantly different (P > 0.05)

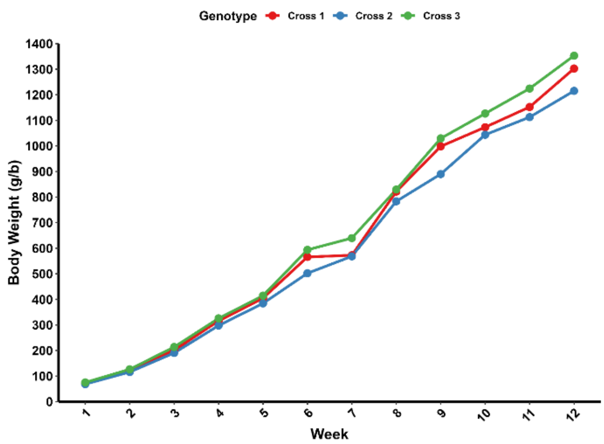

Figure 2. Growth curve of three crosses of chicken from 0-12 wk. of age

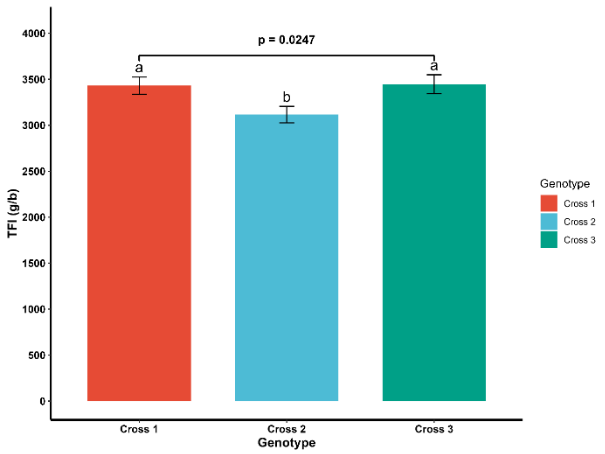

Figure 3. Total feed intake (TFI) of three crosses of chicken from 0-12 wk. of age

Experiment 2: Evaluation of Crossbred Chicken Growth Performance

Growth performance

The growth performance of three different crossbred chicken groups for up to 12 weeks is given in Table 6. Significant differences were observed in the day-old chick (DOC) weight. (P < 0.05), body weight at 12 wk. (P < 0.05) and weight gain (P < 0.05), with Cross 3 outperforming Cross 2 and Cross 1 showing intermediate values. However, the FCR remained statistically similar across crosses (P > 0.05).

Figure 2 displays the growth curves of Cross 1, Cross 2, and Cross 3 from 0 to 12 weeks of age. All genotypes display a progressive increase in body weight, with Cross 3 reaching the highest final weight (1352 g), followed by Cross 1 (1302 g) and Cross 2 (1215 g). Notable differences in weight gain appeared from week 5 onward (P < 0.05).

The body weights at the first week are similar across all genotypes (approximately 100 g), with divergence becoming evident from week 5 onward. Cross 3 consistently outperformed the others, particularly after week 8.

Feed intake

The total feed intake (TFI) of three crosses of chicken from 0 to 12 weeks of age is shown in Figure 3. Results indicate a significant difference (P < 0.05) in TFI among different crosses. The highest TFI was investigated in Cross 3 (3447.25 g/b) and Cross 1 (3431.21 g/b). Conversely, the lowest amount was found in Cross 2 (3115.65 g/b).

Carcass Characteristics

Carcass traits were measured in the three crossbred groups, as shown in Table 7. Significant differences were found in live weight, bled weight, carcass weight, and edible carcass weight (P < 0.05), with Cross 3 consistently displaying higher values compared to Cross 2, while Cross 1 showed intermediate results. No significant differences were detected for individual cut weights (breast, thigh, wing, drum), abdominal fat weight, or dressing percentages.

Discussion

Experiment 1: Conservation and genetic evaluation of exotic chicken germplasms

In a genetic study, when dealing with a lot of linked traits, multi-trait selection is an effective tool for genetic improvement (Ayalew et al., 2017). These models consider how multiple variables interact and help estimate genetic traits for both body weight and egg production at the same time (Lippert et al., 2014; Jannoune et al., 2015). This study comprehensively evaluated the genetic selection parameters, inbreeding rates, and performance traits of four pure lines and their crossbreds in the 20th generation.

The size of the egg is an important economic factor often considered by the consumer; the larger the egg, the higher the price and vice versa (Yahaya et al., 2024). Additionally, egg weight has a vital effect on chick quality, such as hatchability, hatch weight, fitness, and overall chick performance (Enting et al., 2007; Nangsuay et al., 2011). The results of egg production performance among WL, RIR, BPR, and WR reveal distinct breed-specific traits. The highest EW and EP of WL indicate that it is an efficient layer. The results align with the study of Islam et al. (2002) and Yahaya et al. (2024), who found the highest egg weight of WL compared to other breeds. However, a relatively lower egg weight was exhibited by BPR. Several factors, including breed, genotype, and age of laying, have a significant effect on egg size (Biesiada-Drzazga, 2009; Sokołowicz et al., 2012). Following the pattern of higher egg weight, the WL showed higher EP (%) compared to other breeds. Sebho (2016) claims that WL is known for its remarkable egg production, high reproductive capacity, large egg size, efficient feed conversion ratio, and early sexual maturity. Considering the body weight parameter, the RIR breed has gained the highest body weight compared to others, with results similar to those of Khawaja et al. (2012b). However, the lowest body weight was observed in WL, similar to the findings of Glazener et al. (1952). Among all breeds, the WR exhibited the lowest age at sexual maturity, aligning with the study of Ritchil (2011). However, Barua et al. (1992) observed that an early sexual maturity in WL than in RIR. This suggests that the genetic background of the specific strains used and our experimental conditions played a significant role in the timing of sexual maturation.

The highest selection differential and selection response were investigated in WR compared to other breeds in terms of EP (%). In the case of EW, the WL exhibited the highest values for selection differential and selection response. The negative selection response for the ASM of BPR indicates early sexual maturity compared to other lines. Negative selection responses were observed for BW (all lines), suggesting a possible selection against higher body weight. This discrepancy may result from differing selection objectives or environmental interactions influencing trait expression.

The effective population sizes and low rates of inbreeding observed in all lines (WL, RIR, WR, and BPR) are consistent with the findings of Harmon et al. (2010), who emphasized the importance of maintaining effective population sizes above 50 to minimize inbreeding depression.

Experiment 2: Evaluation of Crossbred Chicken Growth Performance

Crossbreeding results illustrate the practical benefits of exploiting heterosis to enhance growth and carcass yield in commercial poultry production (Hoffmann, 2013). Additionally, crossbred chickens demonstrate greater adaptability to diverse environmental conditions, supporting sustainable farming in resource-limited settings (Padhi, 2016). Our study revealed a significant effect of genotype on growth performance. In this study, Cross 3 (RIR x Desi) showed superior body weight gain compared to other crossbreds, including Cross 1 (BPR x Desi) and Cross 2 (Desi x RIR). The findings were consistent with the study of Amao et al. (2019), who observed the highest body weight and body weight gain in RIR x NN crossbreds compared to other crosses. In the reciprocal crosses, differences in performance between Cross 2 and Cross 3 may result not only from heterosis effects but also from maternal or paternal contributions. Amao et al. (2024) found similar results when the improved local chicken shows favorable gene combining effects with the RIR, with growth performance depending on whether RIR is used as the sire (male) or dam (female) line. However, Khawaja et al. (2012a) investigated higher body weight gain in the Fayoumi x RIR cross than in the RIR x Fayoumi cross. There are no notable differences in the feed conversion ratios across crosses, which parallels findings by Sell-Kubiak et al. (2017), who noted that feed efficiency traits are often less responsive to crossbreeding effects than growth traits.

In summary, the superior performance of Cross 3 highlights the significant commercial potential of exploiting heterosis, while the difference from its reciprocal cross emphasizes the important, often overlooked, influence of specific maternal or paternal genetic contributions. Theoretically, these findings illuminate the complex interplay between non-additive genetic variance (heterosis) and additive genetic effects, demonstrating how parental orientation can significantly modulate the outcome of crossbreeding results. Practically, this provides breeders a clear, empirical rationale to move beyond simple crossbreeding and to strategic deployment of specific lines as sires or dams. Therefore, the integration of well-managed pure-line selection with such targeted crossbreeding approaches offers a comprehensive and viable strategy to simultaneously enhance productivity, preserve genetic diversity, and increase profitability in poultry farming.

Conclusion

This study demonstrates that sustained selective breeding in pure-line chickens effectively improves key production traits, as evidenced by a 2.81% selection response for egg production in WR and a 1.96 g response for egg weight in WL, while maintaining genetic diversity ($N_e > 80$, $\Delta F = 0.006$). Crossbreeding generated significant heterosis, with the RIR x Desi cross (Cross 3) achieving a 1352 g body weight at 12 weeks, outperforming its reciprocal cross and underscoring the role of parental contributions. These results provide a validated strategy for breeders: utilize these pure lines and implement crossbreeding schemes that strategically deploy RIR as a sire line to maximize growth heterosis. Future research should apply genomic selection to accelerate genetic gain and genomic mating plans to optimize long-term genetic diversity.

Declarations

Ethical Approval Certificate

The experimental procedures of this study were approved by the Animal Experimentation Ethics and Committee of Bangladesh Livestock Research Institute (Approval date and number: Date:25/05/2023, AEEC/BLRI00113/2023).

Author Contribution Statement

K.N.M.: Conceived the idea, led the research design, coordinated writing, and prepared the manuscript draft. S.S.: Developed research methods and experimental protocols, ensuring the accuracy of the approach. M.R.I.: Assisted in data collection and contributed to analysis and interpretation. S.F.: Provided guidance, ensured scientific rigor, finalized the manuscript, and oversaw submission. M.S.H.: Performed statistical analyses, visualized results, validated findings, and prepared the final manuscript draft.

Conflict of Interests

The authors declare no conflict of interest.

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