

**EVALUATION AND GENETIC ANALYSIS OF
PRODUCTION TRAITS IN RAJASRI BIRDS**

By

MD. NIZAM HUSSAIN
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COLLEGE OF VETERINARY SCIENCE
PVNR TELANGANA VETERINARY UNIVERSITY
RAJENDRANAGAR, HYDERABAD-500 030

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CERTIFICATE

This is to certify that Mr. **MD. NIZAM HUSSAIN** has satisfactorily prosecuted the course of research and that the thesis entitled “**EVALUATION AND GENETIC ANALYSIS OF PRODUCTION TRAITS IN RAJASRI BIRDS**” submitted is the result of original work done and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date: 31.12.2016

(Dr. S.T. VIROJI RAO)

Place: Hyderabad

Major Advisor

CERTIFICATE

This is to certify that the thesis entitled “**EVALUATION AND GENETIC ANALYSIS OF PRODUCTION TRAITS IN RAJASRI BIRDS**” submitted in partial fulfilment of the requirements for the degree of the “**MASTER OF VETERINARY SCIENCE**” of the **PVNR TELANGANA VETERINARY UNIVERSITY** is a record of the bonafide research work carried out by **MD. NIZAM HUSSAIN**, under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by the author of the thesis.

(Dr. S.T. VIROJI RAO)
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairman: **Dr. S.T. VIROJI RAO** _____
Professor and University Head,
Department of Animal Genetics Breeding,
College of Veterinary Science,
Rajendranagar, Hyderabad – 500030

Member: **Dr. M. GNANA PRAKASH** _____
Professor and Head,
Poultry Research Station,
PVNR Telangana Veterinary University,
Rajendranagar, Hyderabad - 500030.

Member: **Dr. DAIDA KRISHNA** _____
Associate Professor & Head,
Department of Poultry Science,
College of Veterinary Science,
Korutla - 505326

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DECLARATION

I, **MD. NIZAM HUSSAIN** hereby declare that the thesis entitled **“EVALUATION AND GENETIC ANALYSIS OF PRODUCTION TRAITS IN RAJASRI BIRDS”** submitted to PVNR Telangana Veterinary University, for the degree of **MASTER OF VETERINARY SCIENCE** is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

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(MD. NIZAM HUSSAIN)

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LIST OF ABBREVIATIONS

%	:	Per cent
\leq	:	Less than or equal to
\pm	:	Plus or Minus
0.01	:	At 1 per cent level of significance
0.05	:	At 5 per cent level of significance
A	:	Aseel
AFE	:	Age at first egg
ANOVA	:	Analysis of Variance
BC	:	Brown Cornish
BN	:	Black Nicobari
BrN	:	Brown Nicobari
BW	:	Body weight
C1 cross	:	Cross of broiler pure – line and a tinted egg layer
C2 cross	:	Cross of broiler pure – line and a tinted egg layer
D	:	Days
DR	:	Delham Red
d.f.	:	Degrees of freedom
EP40	:	Part year egg production up to 40 weeks of age
EW28	:	Egg weight at twenty eight weeks of age
EW40	:	Egg weight at forty weeks of age
<i>et al.</i>	:	Co- workers
F	:	Female
FES	:	Fertile eggs set
FF	:	Frizzle fowl
g	:	Grams
h^2_D	:	Heritability estimate from dam component
h^2_S	:	Heritability estimate from sire component

h^2_{S+D}	:	Heritability estimate from sire + dam component
K	:	Kadaknath
M	:	Male
NN	:	Nacked Neck
P	:	Calculated probability
RIR	:	Rhode Island Red
r_g	:	Correlation coefficient (genetically)
r_p	:	Correlation coefficient (phenotypically)
S	:	Synthetic population
Sig.	:	Significance
WK	:	Week
WLH	:	White Leghorn

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ABSTRACT

The present investigation was carried out to assess the productive and reproductive performance of Rajasri variety of backyard chicken developed by Poultry Research Station, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad.

A total of 2931 chicks produced from 77 sires and 308 dams in 12 hatches during 4th generation were utilized for the present investigation.

Hatch and sex of the birds significantly ($P \leq 0.01$) influenced the body weights at 28, 32, 36 and 40 weeks of age. Significant sexual dimorphism in favour of males was observed. The overall least squares mean body weights at 28, 32, 36 and 40 weeks of age were 1628.38 ± 3.99 , 1693.36 ± 4.00 , 1746.37 ± 4.18 and 1809.11 ± 4.51 g respectively.

Hatch of the birds significantly ($P \leq 0.01$) influenced the AFE, EP40, EW28 and EW40 and the corresponding means were 164.74 ± 0.24 days, 61.00 ± 0.43 , 42.43 ± 0.08 g and 43.79 ± 0.09 g respectively. The mean fertility was 82.65 per cent. The mean hatchability percentage on total egg set (TES) was 72.96 and on fertile egg set (FES) was 88.02.

The average egg shell weight, shell thickness, haugh unit score, albumen index, yolk index and yolk colour were 4.45 ± 0.07 g; 0.33 ± 0.01 mm; 86.31 ± 1.12 ; 0.09 ± 0.01 ; 0.44 ± 0.01 and 6.78 ± 0.16 respectively.

In general, the heritability estimates for body weights were low to moderate. Heritability estimates based on sire, dam and S+D component ranged from 0.03 ± 0.08 (BW28) to 0.13 ± 0.09 (BW32); 0.30 ± 0.14 (BW32) to 0.47 ± 0.15 (BW36) and 0.17 ± 0.08 (BW28) to 0.27 ± 0.09 (BW36) respectively.

The dam component of heritability for AFE was 0.01 ± 0.06 while the heritability estimates based on sire, dam and S+D component for EP40 were 0.06 ± 0.04 , 0.05 ± 0.06 and 0.06 ± 0.04 respectively. The h^2_S , h^2_D and h^2_{S+D} were 0.19 ± 0.06 ; 0.11 ± 0.07 and 0.15 ± 0.08 respectively for EW28 and were 0.10 ± 0.04 ; 0.02 ± 0.06 and 0.06 ± 0.07 respectively for EW40.

Genetic correlation estimates among body weights studied were positive and high in magnitude ranging from 0.62 ± 0.16 (BW28 – BW40) to 0.98 ± 0.08 (BW36 – BW40). The genetic correlation of AFE with all other traits was not estimable while the genetic correlation of EP40 with body weights was negative in direction and low in magnitude.

The phenotypic correlations among body weights were positive and high in magnitude ranging from 0.50 ± 0.02 (BW28 – BW40) to 0.83 ± 0.01 (BW28 – BW32). Whereas, phenotypic correlations observed between AFE and body weights in the present study were positive but low in magnitude, the correlation of AFE with EP40 and EW40 were negative.

“Rajasri” is a synthetic variety evolved by synthetic breeding of three exotic layer breeds and local non-descript fowl. Productive performance of Rajasri birds was comparable with other backyard varieties like Grampriya, Vanaraja etc. Heritability estimates were low to medium for body weight at different ages and low for various production traits.

CHAPTER I

INTRODUCTION

Poultry farming is one of the fastest growing segments of agriculture in India. It carries a pivotal position in current Indian economy and has evolved as an extremely business oriented enterprise (Sreenivas *et al.*, 2013). In a developing country like India, growth in the livestock sector can definitely contribute to poverty alleviation, as the largest share of the rural poor depends on livestock for their daily livelihoods. In India, present per-capita availability of egg and meat are 61 eggs and 2.8 kg respectively, as against the ICMR recommendation of 180 eggs and 11 kg meat. Therefore, to bridge the gap between availability and requirement, the broiler and layer industries have to be up scaled by 3 to 5 folds which is an uphill task. Though major share of the poultry products come from commercial poultry sector, share of backyard poultry is substantial. Moreover, *desi* eggs and chicken are well appreciated for their taste and texture, in both rural and urban markets.

Backyard poultry production system is a low input or no input activity and is characterized by indigenous night shelter, scavenging with little supplementary feeding, natural hatching of chicks, poor productivity of birds, local marketing, and no health care practice (Mandal *et al.*, 2006). It provides an additional income and enhances nutrition of rural households besides enhancing soil fertility.

Realizing the importance of backyard poultry, several research institutes initiated projects for evolving suitable genetic groups with higher productivity. University of Agricultural Sciences, Bangalore developed the first synthetic variety “Giriraja” utilizing White Plymouth Rock, Red Cornish and New Hampshire breeds in the year 1989. Similarly, Directorate of Poultry Research, Hyderabad developed Vanaraja, Srinidhi and Gramapriya varieties with exotic broiler inheritance. Central Avian Research Institute, Izatnagar crossed native breeds with exotic layer breeds to develop CARI – Gold, CARI – Shyama, HIT – CARI, UP – CARI. Directorate of Poultry Research, Central Avian Research Institute, Izatnagar and Tamil Nadu Veterinary and Animal Sciences University, Chennai also released synthetic genotypes with broiler parent inheritance like Krishibro, CARI-Bro Dhanraja and Cari-Bro Mrityunjay; and Nandanam broiler respectively. Karnataka Veterinary Animal and Fishery Science University, Bidar evolved a dual purpose breed Swarnadhara. Subsequently, several varieties were developed by Government and private agencies with varying acceptability by the farming community. Many of these varieties were either straight crosses of exotic breeds or exotic breeds crossed with native breeds.

A need was felt by P.V. Narsimha Rao Telangana Veterinary University to develop a bird having medium body size, long shanks, better flight, egg production of 125-150 eggs per annum under free range conditions, ability to resist common diseases and with stand adverse climatic conditions. In tune with the felt need, Poultry Research Station of PVNR Telangana Veterinary University, Hyderabad took the initiative to develop a synthetic variety with 56.25% Rhode Island Red, 6.25% White Leghorn, 12.50% Dahlem Red and 25% native chicken inheritance. The genotype so

developed was stabilized by *inter-se* mating and named as “RAJASRI”.

The present study is taken up to evaluate these birds with the following specific objectives.

- 1) To study the growth performance of Rajasri birds.
- 2) To evaluate the productive and reproductive potential of the stock using part year production records.
- 3) To study egg quality traits in these birds.

CHAPTER II

REVIEW OF LITERATURE

2.1 BODY WEIGHTS

Bird's body weight and body conformation determine the suitability of a genotype / breed / variety to backyard production system. It gives an indication about growth rate also. Published literature on body weight at different ages *viz.*, 28, 32, 36 and 40 weeks of age pertaining to commercial and backyard poultry genotypes are reviewed below.

2.1.1 Body weight at 28 weeks of age

The mean body weight at 28 weeks of age in Lohmann brown chicken was 1824.28 ± 25.08 g (Usturoi *et al.* 2006) and in Vanaraja males and females was 3505.27 ± 328 and 2885.69 ± 145 g, respectively (Kalita *et al.*, 2012) under intensive system of rearing.

2.1.2 Body weight at 32 weeks of age

Usturoi *et al.* (2006) studied the growth performance of Lohmann brown chicken and found that the average body weight at 32 weeks of age was 1837.79 ± 29.61 g. Padhi and Chatterjee (2012) reported that the average body weight of PD1 (Vanaraja male line) selected females at 32 weeks was 2521 ± 0.65 g.

Table 1. Average body weight (g) at 40 weeks of age as reported in literature

BREED / VARIETIES	MEAN \pm S.E	AUTHOR (s)
Native breeds		
Danki ($\sigma^{\text{♂}}$ - Field)	3115.00 \pm 0.09	Vij <i>et al.</i> (2006)
Danki ($\sigma^{\text{♀}}$ - Field)	2223.00 \pm 0.06	
Ghagus ($\sigma^{\text{♂}}$ - Field)	2160.00 \pm 0.25	
Ghagus ($\sigma^{\text{♀}}$ - Field)	1433.00 \pm 0.81	
Kalasathi ($\sigma^{\text{♂}}$ - Field)	2482.00 \pm 0.13	
Kalasathi ($\sigma^{\text{♀}}$ - Field)	1850.00 \pm 0.10	
Aseel (A - Farm)	1805.00	Niranjan <i>et al.</i> (2008a)
Kadakhnath (K - Farm)	1259.00	
Miri type ($\sigma^{\text{♂}}$ - Farm)	1507.00 \pm 44.70	Haunshi <i>et al.</i> (2009)
Miri type ($\sigma^{\text{♀}}$ - Farm)	1214.14 \pm 20.65	
Aseel ($\sigma^{\text{♂}}$ -Farm)	2736.9 \pm 50.8	Haunshi <i>et al.</i> (2011)
Aseel ($\sigma^{\text{♀}}$ -Farm)	1831.6 \pm 25.8	
Kadakhnath (K) ($\sigma^{\text{♂}}$ -Farm)	1739.8 \pm 30.9	
Kadakhnath (K) ($\sigma^{\text{♀}}$ -Farm)	1321.6 \pm 18.4	
Naked neck (Farm)	3046.89 \pm 3.29	Rajkumar <i>et al.</i> (2012d)
Aseel	1156.41 \pm 8.79	Jha and Prasad (2013)
Hazra	1472.85 \pm 9.76	Jha <i>et al.</i> (2013a)
Aseel (Farm)	1326.45 \pm 8.75	
Kadakhnath (K) (Farm)	1248.12 \pm 9.31	
Dahlem Red	1795.17 \pm 4.25	Jha <i>et al.</i> (2013b)
Dahlem Red X Desi	1724.58 \pm 4.63	
Dahlem Red	2340.30 \pm 48.50	Kalita <i>et al.</i> (2015)

(Contd...)

Table 1 (Contd...)

Exotic layer breeds and their crosses		
WLH	1434.71 ± 4.21	Kataria and Johari (2001)
RIR	1993.79 ± 7.18	
RIR (Farm)	1673.24 ± 5.64	Jilani <i>et al.</i> (2005)
RIR	1673.24 ± 5.64	Jilani <i>et al.</i> (2007)
IWH	1443.12 ± 0.32	Chatterjee <i>et al.</i> (2008)
IWI	1443.52 ± 0.28	
IWK	1510.93 ± 0.32	
Control(WLH)	1505.85 ± 0.60	
IWH	1407.73 ± 7.66	Jayalaxmi <i>et al.</i> (2008)
IWI	1422.88 ± 6.93	
IWK	1410.95 ± 8.12	
Control(WLH)	1484.59 ± 7.39	
WLH (IWN strain) (Farm)	1563.00 ± 0.00	Anees <i>et al.</i> (2010)
WLH (IWH strain) (Farm)	1407.73 ± 7.66	Jayalaxmi <i>et al.</i> (2010)
WLH (IWK strain) (Farm)	1410.95 ± 8.12	
Dwarf chicken	2511.01± 2.81	Rajkumar <i>et al.</i> (2011a)
IWH	1311.32 ± 7.09	Sreenivas (2013)
IWI	1322.13 ± 7.74	
IWK	1290.74 ± 7.21	
Control(WLH)	1428.36 ± 8.36	
CARI-Sonali	1775.74 ± 21.83	Das <i>et al.</i> (2014)
CARI-Debendra	1744.78 ± 8.86	
RIR ^s	2122.34 ± 25.54	
RIR ^c	1747.65 ± 14.44	
RIR ^w	1766.87 ± 29.01	

(Contd...)

Table 1 (Contd...)

Native breed crossed with exotic layer breeds		
Rajasri (♂ - Farm)	1950 ± 8.36	Rao <i>et al.</i> (2008)
Rajasri (♂ - Farm)	1950 ± 8.36	
CARI - Shyama (♂ - Farm)	2073 ± 0.05	Malik <i>et al.</i> (2009)
CARI - Shyama (♀ - Farm)	1777 ± 0.04	
CARI - Shyama (♂ - Field)	2031 ± 0.08	
CARI - Shyama (♀ - Field)	1700 ± 0.03	
CARI - Nirbheek (♂ - Farm)	2660 ± 0.04	Malik and Singh (2010)
CARI - Nirbheek (♀ - Farm)	2091 ± 0.03	
CARI - Nirbheek (♂ - Field)	2462 ± 0.28	
CARI - Nirbheek (♀ - Field)	2021 ± 0.06	
Rajasri	1316 ± 9.98 to 1657 ± 7.27	Rao and Narasimha (2012)
Rajasri (♀)	1529 ± 8.86	Rao <i>et al.</i> (2012)
Rajasri (♂)	1950 ± 8.36	
Type I (♀)	1557 ± 19.29	Rao <i>et al.</i> (2012a)
Type II (♀)	1549 ± 12.84	
Exotic breeds crossed / synthetic genotypes with broiler parent inheritance		
Krishna – J	1186	Khan (2001)
Vanaraja (♂- Field)	3150	Niranjan and Singh (2005)
Vanaraja (♀- Field)	2580	
Gramapriya (Field)	2614	
Gramapriya (Farm)	2773	
C1 cross (Farm)	2641.61 ± 25.51	Niranjan <i>et al.</i> (2008b)
C2 cross (Farm)	2456.64 ± 29.84	
Vanaraja (Farm)	2561.30 ± 20.53	
Gramapriya (Farm)	2304.25 ± 20.41	

(Contd...)

Table 1(Contd...)

Gramapriya (♂ - Farm)	2544.20 ± 62.24	Haunshi <i>et al.</i> (2009)
Gramapriya (♀ - Farm)	1810.42 ± 60.38	
Vanaraja (♂- Farm)	3323.00 ± 64.08	
Vanaraja (♀- Farm)	2277.00 ± 37.02	
Vanaraja (♂- Farm)	4420.45 ± 310	Kalita <i>et al.</i> (2012)
Vanaraja (♀- Farm)	3120.68 ± 205	
Gramapriya (Farm)	2443.47 ± 18.12	Rajkumar <i>et al.</i> (2012)
DW X PB2	2999.94 ± 66.55	Rajkumar <i>et al.</i> (2012b)
PB2 X DW	3072.13 ± 59.24	
PD1 (♀- Farm)	2703 ± 0.77	Padhi and Chatterjee <i>et al.</i> (2012)
Gramapriya	1828.17 ± 9.51	Jha and Prasad (2013)
Vanaraja	2467.83 ± 11.36	
Vanaraja (Field)	2976.61 ± 18.08	Islam <i>et al.</i> (2014)
PD1 x PD4 (♂- Farm)	2784 ± 99	Padhi <i>et al.</i> (2014)
PD1 x PD4 (♀- Farm)	1978 ± 68	
Gramapriya (Field)	2031.75 ± 26.14	Hajra <i>et al.</i> (2014)
Vanaraja (Field)	2280.00 ± 35.06	
PD1×PD4 (♀- Farm)	2227 ± 25	Padhi <i>et al.</i> (2015b)
PD1×PB2 (♀- Farm)	2844 ± 40	
PD1×PD3 (♀- Farm)	2237 ± 23	
PD1×IWI (♀- Farm)	2071 ± 25	
PD1	2903 ± 0.91	Padhi <i>et al.</i> (2015)
PD1	2647 ± 0.50	Padhi <i>et al.</i> (2015a)
PD1 X IWI X PD3 (♀- Farm)	1971 ± 26	Padhi <i>et al.</i> (2016)
Vanaraja (♂- Farm)	3265 ± 10.91	Sankhyan and Thakur (2016)
Vanaraja (♀- Farm)	2318 ± 11.88	

Kalita *et al.* (2012) studied the performance of Vanaraja birds and reported that the body weight at 32 weeks of age averaged 4000.31 ± 350 g in males and 2990.72 ± 196 g in females under intensive system of rearing.

2.1.3 Body weight at 36 weeks of age

Usturoi *et al.* (2006) evaluated the performance of Lohmann brown and found that the mean body weight of these birds at 36 weeks of age was 1850.18 ± 30.36 g.

2.1.4 Body weight at 40 weeks of age

Published results on body weight at 40 weeks of age (BW40) pertaining to various backyard poultry varieties are compiled and presented in Table (1). Significant differences among genotypes were reported for BW40 (Vij *et al.*, 2006; Niranjana *et al.*, 2008b).

Perusal of published results pertaining to native breeds for BW40 indicated wide variation. It ranged from 1214.14 ± 20.65 g in Miri females (Haunshi *et al.*, 2009) to 3115.00 ± 0.09 g in Danki males (Vij *et al.*, 2006).

The mean BW40 among various exotic layer breeds and their crosses ranged from 1290.74 ± 7.21 g in IWK (Sreenivas, 2013) to 2122.34 ± 25.54 g in RIR (Das *et al.*, 2014). The BW40 among backyard varieties developed by crossing native breeds with exotic layer breeds varied from 1316 ± 9.98 in Rajasri (Rao and Narasimha, 2012) to 2073 ± 0.05 g in CARI-Shyama males (Malik *et al.*, 2009). Whereas, BW40

among backyard varieties with broiler inheritance ranged from 1810 ± 60.38 g in Gramapriya females to 3323.00 ± 64.08 g in Vanaraja males (Haunshi *et al.*, 2009).

2.2 PERFORMANCE OF PRODUCTIVE TRAITS

2.2.1 Age at first egg (AFE)

Age at first egg is an important economic trait which influences the annual egg production. The average AFE of various genotypes/breeds as reported in published literature are presented in Table (2).

Significant differences between genotypes/breeds were reported in the literature. (Niranjan *et al.*, 2008; Jha *et al.*, 2013a; Niranjan *et al.*, 2008a; Singh *et al.*, 2000; Rajkumar *et al.*, 2011; Singh, 2001).

Perusal of Table (2) indicated wide variation in AFE. In general, native chicken recorded highest AFE followed by varieties having certain level of native inheritance and pure exotic breeds in that order.

In general, AFE of native breeds ranged from 147 days in Miri – type chicken (Haunshi *et al.*, 2009) to 202 days in Aseel (Singh, 2001) which seemed to be late maturing. Age at first egg was 28.94 weeks in Aseel and 7.37, 5.75 and 7.16 months in Danki, Ghagus and Kalasthi breeds of native chicken under field conditions (Singh *et al.*, 2000; Vij *et al.*, 2006).

Wide within breed variation was also reported for AFE. The AFE ranged

Table 2. Average age at first egg (in days) as reported in literature

BREED/ VARIETIES	MEAN \pm S.E	AUTHOR (s)
Native breeds		
Aseel (in weeks)	28.94	Singh <i>et al.</i> (2000)
Black Nicobari	177.00 \pm 2.30	Ahlawat and Padhi (2001)
White Nicobari	174.00 \pm 1.4	
Brown Nicobari (BrN)	198.00 \pm 6.00	
Nicobari	184.00 \pm 1.31	
Naked neck	189.00 \pm 3.01	Padhi <i>et al.</i> (2001)
Frizzle Fowl (FF)	192.00 \pm 4.03	
Kadakhnath	194	Singh (2001)
Aseel (A)	202.00 \pm 2.39	
Naked neck	201	
Danki (in months)	7.37 \pm 0.03	Vij <i>et al.</i> (2006)
Ghagus (in months)	5.75 \pm 0.25	
Kalasthi (in months)	7.16 \pm 0.24	
Kadakhnath (Farm)	159.00	Niranjan <i>et al.</i> (2008a)
Aseel	164	
Miri type	147.00 \pm 1.10	Haunshi <i>et al.</i> (2009)
Aseel	176	Haunshi <i>et al.</i> (2011)
Kadakhnath (K)	175	
Horro	190.00 \pm 1.77	Dana <i>et al.</i> (2011)
Aseel (Farm)	186.00 \pm 1.64	Barman <i>et al.</i> (2011)
Kadakhnath (K) (Farm)	196.00 \pm 1.34	Jha <i>et al.</i> (2011)
Dwarf chicken	153.06 \pm 0.06	Rajkumar <i>et al.</i> (2011a)
Naked neck (NN) (Farm)	160.11 \pm 0.09	RajKumar <i>et al.</i> (2012d)
Mazandaran Native chicken	165.5	Niknafs <i>et al.</i> (2012)

(Contd...)

Table 2 (Contd...)

Aseel	192.83 ± 1.64	Jha and Prasad (2013)
Hazra	178.98 ± 1.63	Jha <i>et al.</i> (2013a)
Aseel (Farm)	187.43 ± 1.54	
Kadaknath (K) (Farm)	196.12 ± 1.75	
Dahlem Red	143.65 ± 1.76	
Dahlem Red X Desi	171.38 ± 1.42	Jha <i>et al.</i> (2013b)
Esfahan native chicken	179.26	Yousefi <i>et al.</i> (2013)
White Nicobari (WN)	137	Kundu <i>et al.</i> (2015)
Black Nicobari (BN)	140	
Brown Nicobari (BrN)	202	
Dahlem Red	158.23 ± 2.75	Kalita <i>et al.</i> (2015)
Exotic breeds and their crosses		
White Leghorn (WLH)	156.00 ± 2.00	Ahlawat and Padhi (2001)
WLH	135.25 ± 0.18	Kataria and Johari (2001)
CARI – Gold	121.00	
RIR	149.66 ± 0.38	
Dahlem Red (DR)	158.00	Singh (2001)
Rhode Island Red (RIR) (Farm)	146.16 ± 0.33	Jilani <i>et al.</i> (2005)
RIR	146.16 ± 0.33	Jilani <i>et al.</i> (2007)
IWH	159.32 ± 2.79	Chatterjee <i>et al.</i> (2008)
IWI	159.32 ± 2.61	
IWK	146.13 ± 1.77	
Control (WLH)	158.36 ± 2.20	
IWH	141.71 ± 0.41	Jayalaxmi <i>et al.</i> (2008)
IWI	148.20 ± 0.43	
IWK	143.45 ± 0.43	
Control (WLH)	148.49 ± 0.51	

(Contd...)

Table 2 (Contd...)

CARI – Gold	170.50 ± 2.35	Mallick and Ghosh (2008)
CARI – Gold	175.38 ± 5.39	
WLH (IWN strain) (Farm)	151.38 ± 0.09	Anees <i>et al.</i> (2010)
WLH (IWH strain) (Farm)	141.71 ± 0.41	Jayalaxmi <i>et al.</i> (2010)
WLH (IWK strain) (Farm)	143.45 ± 0.43	
Dahlem Red	181.02	Prasad <i>et al.</i> (2012)
IWH	143.49 ± 0.56	Sreenivas (2013)
IWI	148.18 ± 0.61	
IWK	155.63 ± 0.57	
Control (WLH)	150.9 ± 0.66	
FF	144.29 ± 0.10	Basant <i>et al.</i> (2013)
RR	144.66 ± 0.13	
FR	142.00 ± 0.04	
RF	142.00 ± 0.08	
RIR ^s	148.86 ± 0.78	Das <i>et al.</i> (2014)
RIR ^c	177.23 ± 1.92	
RIR ^w	169.33 ± 2.55	
CARI-Sonali	135.06 ± 1.27	
CARI-Debendra	177.73 ± 2.25	
White Leghorn	133.85 ± 5.65	Yi <i>et al.</i> (2014)
Brown Egg Dwarf	134.88 ± 9.47	
Native breeds crossed with exotic layer breeds		
BrN × WLH	187.00 ± 4.00	Ahlawat and Padhi (2001)
WLH × BrN	170.00 ± 11.00	
DR × A	181.50	Singh (2001)
A × DR	183.40	

(Contd...)

Table 2 (Contd...)

CARI – Nirbheek	173	Singh <i>et al.</i> (2004)	
HIT – CARI	167		
UP – CARI	162		
CARI – Shyama	165	Singh (2005)	
CARI - Nirbheek (Field)	174		
CARI - Nirbheek (Farm)	176		
CARI - Shyama (Field)	167		
CARI - Shyama (Farm)	170		
HIT - CARI (Field)	172		
HIT - CARI (Farm)	178		
UP - CARI (Farm & Field)	165		
ILI80 × Br.Nic (Cages)	167 ± 2.14		Chatterjee <i>et al.</i> (2007a)
Br.Nic × ILI80 (Cages)	176 ± 2.86		
ILI80 × Br.Nic (Field)	189 ± 3.55		
Br.Nic × ILI80 (Field)	191 ± 2.53		
CARI – Nirbheek	174	Kumar <i>et al.</i> (2008a)	
CARI – Shyama	167.50		
Rajasri	161.83 ± 0.23	Rao <i>et al.</i> (2008)	
CARI - Shyama (Farm)	193.00 ± 0.49	Malik <i>et al.</i> (2009)	
CARI - Shyama (Field)	201.26 ± 1.87		
CARI - Nirbheek (Farm)	187.16 ± 0.35	Malik and Singh (2010)	
CARI - Nirbheek (Field)	198.04 ± 1.70		
Vanaraja	181.2 ± 1.85	Ramana <i>et al.</i> (2010)	
A × WLH	168.00 ± 1.05	Rao <i>et al.</i> (2010)	
A × Synthetic population	193.00 ± 0.83		
CARI - Nirbheek (Farm)	191	Chakravarthi <i>et al.</i> (2012)	
Vanaraja	147.50 ± 5.46	Kalita <i>et al.</i> (2012)	

(Contd...)

Table 2 (Contd...)

Rajasri	179	Daida <i>et al.</i> (2012)
Rajasri	161.83 ± 0.23	Rao <i>et al.</i> (2012)
Type-I(F3)	154 ± 1.57	Rao <i>et al.</i> (2012a)
Type-II(F3)	145 ± 0.91	
Rajasri	145 ± 0.25 to 161 ± 0.25	Rao and Narasimha (2012)
Rajasri	165	Naga Raja Kumari <i>et al.</i> (2014)
Native breed crossed with exotic broiler breeds		
NN × Synthetic Broiler (SB)	178	Padhi <i>et al.</i> (2001)
SB × FF	186	
Exotic breeds / synthetic genotypes with broiler parent inheritance		
Krishna – J	180	Khan (2001)
Giriraja	170 – 180	Ramappa (2001)
Vanaraja	172 – 185	Bhattacharya <i>et al.</i> (2005)
Vanaraja	171	Kumar <i>et al.</i> (2005)
Gramapriya (Field)	193.60	Niranjan and Singh (2005)
Gramapriya (Farm)	127.00	
CARI – Debendra (Semi–intensive)	147.25 ± 4.28	Mallick and Ghosh (2008)
CARI – Debendra (Field)	166.52 ± 5.35	
Vanaraja (Semi–intensive)	175.38 ± 5.00	
Vanaraja (Field)	172.52 ± 5.35	
Gramapriya (Semi–intensive)	175.35 ± 5.56	
Gramapriya (Field)	162.35 ± 3.23	
C1 cross	154.67 ± 0.81	Niranjan <i>et al.</i> (2008b)
C2cross	145.72 ± 1.11	
Gramapriya	160.89 ± 0.63	
Vanaraja	164.79 ± 0.58	

(Contd...)

Table 2 (Contd...)

Gramapriya	179.50 ± 0.96	Haunshi <i>et al.</i> (2009)
Vanaraja	197.70 ± 1.26	
Vanaraja	175-180	Rajkumar <i>et al.</i> (2010)
Gramapriya	160-165	
Gramapriya	184.00	jaya <i>et al.</i> (2012)
Vanaraja	147.50 ± 5.46	Kalita <i>et al.</i> (2012)
Gramapriya	161 – 165	Prakash <i>et al.</i> (2012)
Gramapriya	156.19 ± 0.03	Rajkumar <i>et al.</i> (2012)
Gramapriya (Intensive)	138.46 ± 2.08	Giri and Sahoo (2012)
Gramapriya (Extensive)	142.25 ± 5.26	
FF	144.29 ± 0.10	Basant <i>et al.</i> (2013)
RR	144.66 ± 0.13	Basant <i>et al.</i> (2013)
FR	142.00 ± 0.04	
RF	142.00 ± 0.08	
Vanaraja	161.58 ± 1.67	
Gramapriya	155.32 ± 1.76	Jha and Prasad (2013)
Gramapriya (Deep litter)	151.58	Patel <i>et al.</i> (2013)
Gramapriya (Semi-Intensive)	153.32	
Gramapriya (Field)	168.83	
Vanaraja (Field)	152	Pathak and Nath (2013)
Gramapriya (Field)	145	
RIFI	146 ± 2.51	Khawaja <i>et al.</i> (2013)
FIRI	149 ± 1.51	
RLH	150 ± 1.50	
Vanaraja	178.13 ± 0.79	Deka <i>et al.</i> (2014)
Vanaraja (Field)	181.53 ± 1.29	Hajra <i>et al.</i> (2014)
Gramapriya (Field)	173 ± 1.35	

(Contd...)

Table 2 (Contd...)

Vanaraja	187.45 ± 1.02	Islam <i>et al.</i> (2014)
Vanaraja (Van)	145	Kundu <i>et al.</i> (2015)
(Van × WN)	181	
(WN × Van),	146	
(Van × BN)	187	
(BN × Van)	191	
(Van × BrN)	184	
(BrN × Van)	165	
PD1×PD4	157 ± 2.00	Padhi <i>et al.</i> (2015b)
PD1×PB2	160 ± 1.79	Padhi <i>et al.</i> (2015b)
PD1×PD3	158 ± 1.10	
PD1×IWI	149 ± 0.64	
PD1	180.30 ± 0.05	Padhi <i>et al.</i> (2015)
PD1	188.58 ± 0.05	Padhi <i>et al.</i> (2015a)
PD1 X IWI X PD3	163.14	Padhi <i>et al.</i> (2016)
Vanaraja	162	Sankhyan and Thakur (2016)

from 159 to 196.12 ± 1.75 days in Kadakntah (Niranjan *et al.*, 2008 and Jha *et al.*, 2013a) and from 164 ± 0.09 to 202.00 ± 2.39 days in Naked neck birds (Rajkumar *et al.*, 2011; Singh, 2001).

Among the exotic breed crosses or synthetic genotypes, the AFE ranged from 127 days in Gramapriya (Niranjan and Singh, 2005) to 198 days in Vanaraja (Haunshi *et al.*, 2009). While AFE among genotypes evolved by crossing native breeds with exotic layer type breeds ranged from 145 ± 0.25 days in Rajasri (Rao and Narasimha, 2012) to 198.04 ± 1.70 days in CARI-Nirbheek (Malik and Singh, 2010).

The AFE among genotypes evolved by using broiler breeds ranged between 127 days in Gramapriya (Niranjan and Singh, 2005) to 197 ± 1.26 days in Vanaraja (Haunshi *et al.*, 2009).

It was also reported that type of rearing also affected AFE. In general, birds reared in farms matured earlier than birds reared under free range system which might be due to availability of balanced diet (Malik *et al.*., 2009; Malik and Singh, 2010; Chakravarthi *et al.*, 2012).

2.2.2 Part year egg production up to 40 weeks of age (EP40)

Egg production is one of the important economic traits in poultry which influenced the acceptability of variety / breed in backyard production. The part year egg productions up to 40 weeks of age reported for various genotypes / breeds are presented in Table (3).

Perusal of literature indicated that there was significant variation within the genetic groups (Ayyagari, 2001; Kumar *et al.*, 2008a; Haunshi *et al.*, 2009; Malik and Singh, 2010; Giri and Sahoo, 2012).

Native chicken breeds are poor producers. Egg production up to 40 weeks among native breeds ranged from 12.52 ± 3.46 eggs in Kadaknath (Jha *et al.*, 2013a) to 64.18 eggs in Naked neck (Rajkumar *et al.*, 2011). Whereas EP40 among exotic layer breeds, their crosses or synthetic varieties evolved using exotic layer breeds ranged from 72.57 ± 3.46 eggs in Dahlem red (Jha *et al.*, 2013b) to 112.87 ± 0.44 eggs in WLH (Kataria and Johari, 2001). The part year egg production up to 40 weeks of age in genotypes evolved using broiler breeds as one of the parent ranged between 22.20 ± 0.88 eggs in Vanaraja birds (Hajra *et al.*, 2014) to 99.88 ± 1.84 eggs in C1 cross (Niranjan *et al.*, 2008b).

Niranjan and Singh (2005) and Giri and Sahoo (2012) also reported that birds reared in farms produced more eggs than birds reared under field / extensive system of rearing.

Table 3. Average part year egg production (in No.) up to 40 weeks of age (EP40) as reported in literature

BREED / VARIETIES	MEAN \pm S.E.	AUTHOR (s)
Native breeds		
Kadaknath	42.62	Niranjan <i>et al.</i> (2008a)
Aseel	31.30	
Miri type	33.59 \pm 0.99	Haunshi <i>et al.</i> (2009)
Aseel (Farm)	36.23	Haunshi <i>et al.</i> (2011)
Kadaknath (K) (Farm)	49.40	
Naked neck	64.18 \pm 0.13	Rajkumar <i>et al.</i> (2012d)
Dwarf chicken	79.10 \pm 0.15	Rajkumar <i>et al.</i> (2011a)
Hazra	18.76 \pm 3.74	Jha <i>et al.</i> (2013a)
Aseel (Farm)	15.83 \pm 3.75	
Kadaknath (K) (Farm)	12.52 \pm 3.46	
Exotic layer breeds and their crosses		
White Leghorn (WLH)	112.87 \pm 0.44	Kataria and Johari (2001)
Rhode Island Red (RIR)	96.47 \pm 0.67	
RIR	107.19 \pm 0.10	Jilani <i>et al.</i> (2005)
RIR	107.16 \pm 0.10	Jilani <i>et al.</i> (2007)
IWH	100.83 \pm 0.05	Chatterjee <i>et al.</i> (2008)
IWI	97.30 \pm 4.50	
IWK	98.38 \pm 4.10	
Control(WLH)	88.84 \pm 5.32	
IWH	108.77 \pm 0.65	Jayalaxmi <i>et al.</i> (2008)
IWI	105.59 \pm 0.55	
IWK	102.39 \pm 0.73	
Control (WLH)	97.14 \pm 0.71	

(Contd...)

Table 3 (Contd...)

CARI – Gold (per month)	15 to 18	Mallick and Ghosh (2008)
WLH (IWH strain)	108.77 ± 0.65	Jayalaxmi <i>et al.</i> (2010)
Dahlem Red (DR)	71.06	Prasad <i>et al.</i> (2012)
IWH	106.15 ± 0.49	Sreenivas (2013)
IWI	100.21 ± 0.53	
IWK	94.08 ± 0.50	
Control (WLH)	97.29 ± 0.57	
Aseel	16.43 ± 3.72	Jha and Prasad (2013)
Dahlem Red	72.57 ± 3.46	Jha <i>et al.</i> (2013b)
Dahlem Red X Desi	58.26 ± 3.58	
RIR	96.45 ± 0.99	Das <i>et al.</i> (2014)
RIR	60.79 ± 2.43	
RIR	71.61 ± 3.24	
Cari-Sonali	111.13 ± 1.61	
CARI-Debendra	66.23 ± 2.85	
Dahlem Red	82.56 ± 5.75	Kalita <i>et al.</i> (2015)
Native breed crossed with exotic layer breeds		
CARI – Nirbheek	56.75	Kumar <i>et al.</i> (2008a)
CARI – Shyama	57.00	
CARI - Shyama (Farm)	29.76	Malik <i>et al.</i> (2009)
CARI - Shyama (Field)	25.26	
CARI - Nirbheek (Farm)	37.32	Malik and Singh (2010)
CARI - Nirbheek (Field)	26.31	
A × WLH	76.43 ± 1.87	Rao <i>et al.</i> (2010)
A × Synthetic Population	50.47 ± 1.28	
Rajasri	63.98 ± 0.68	Rao <i>et al.</i> (2012)
Type-I(F3)	76 ± 1.66	Rao <i>et al.</i> (2012a)
Type-II(F3)	79 ± 1.07	

(Contd...)

Table 3 (Contd...)

Exotic breeds / synthetic genotypes with broiler parent inheritance		
Vanaraja	55 – 65	Ayyagari (2001)
Krishna – J	90 – 120	Khan (2001)
Giriraja	65 – 70	Ramappa (2001)
Gramapriya (Field)	34.62	Niranjan and Singh (2005)
Gramapriya (Farm)	62.13	
CARI - Debendra (per month)	12 to 14	Mallick and Ghosh (2008)
Vanaraja (per month)	14 to 16	
Gramapriya (per month)	12 to 15	
C1 cross	99.88 ± 1.84	Niranjan <i>et al.</i> (2008b)
C2 cross	88.59 ± 2.28	
Gramapriya (HDEP)	26.82 ± 1.62	Haunshi <i>et al.</i> (2009)
Vanaraja (HDEP)	13.37 ± 1.09	
Vanaraja	52.8 ± 3.64	Ramana <i>et al.</i> (2010)
Vanaraja	53.25 ± 5.61	Kalita <i>et al.</i> (2012)
Gramapriya (Intensive)	93.25 ± 3.66	Giri and Sahoo (2012)
Gramapriya (Extensive)	78.00 ± 4.65	
DW X PB2 CROSS	47.56 ± 0.74	Rajkumar <i>et al.</i> (2012b)
PB2 XDW CROSS	48.99 ± 0.55	
Vanaraja	48.26 ± 3.84	Jha and Prasad (2013)
Gramapriya	67.42 ± 3.56	
Gramapriya	30.40 ± 1.06	Hajra <i>et al.</i> (2014)
Vanaraja	22.20 ± 0.88	
Vanaraja	52.08 ± 0.32	Islam <i>et al.</i> (2014)
PD1×PD4	26.12	Padhi <i>et al.</i> (2014)

(Contd...)

Table 3 (Contd...)

PD1×PD4	70.50 ± 0.44	Padhi <i>et al.</i> (2015b)
PD1×PB2	55.29 ± 2.18	
PD1×PD3	88.78 ± 2.17	
PD1×IWI	92.43 ± 1.45	
PD1	42.34 ± 0.05	Padhi <i>et al.</i> (2015)
PD1	46.29 ± 0.04	Padhi <i>et al.</i> (2015a)
PD1 X IWI X PD3	91.71 ± 1.37	Padhi <i>et al.</i> (2016)
Vanaraja (HDEP)	50.12	Sankhyan and Thakur (2016)

2.2.3 Egg weight

Egg weight is an important trait which determines the price. It is influenced by the body weight of the bird and genetic group.

2.2.3.1 Egg weight at 28 weeks of age

The average egg weight at 28 weeks of age as reported in the literature are presented in Table (4). The egg weight at 28 weeks among native genotypes ranged from 35.58 ± 0.34 in Kadaknath (Haunshi *et al.*, 2010) to 53.67 in Naked neck (Rajkumar *et al.*, 2009). The same for exotic layer breeds ranged from 43.46 ± 0.50 in RIR^c (Das *et al.*, 2014) to 49.61 ± 7.16 in IWK strain (Chatterjee *et al.*, 2008). In case of crossbreds, it ranged from 45.6 ± 0.23 in Type-II (Rao *et al.*, 2012a) to 52.08 ± 0.29 in C1 cross (Niranjan *et al.*, 2008).

2.2.3.2 Egg weight at 40 weeks of age

Perusal of the published literature on egg weight at 40 weeks of age (Table 5) indicated that the native chicken breeds were producing small to large sized eggs weighing between 38.67 g (Miri type chicken reported by Haunshi *et al.*, 2009) to 60.61 ± 0.04 g (Aseel chicken reported by Rajkumar *et al.*, 2011). Egg weight at 40 weeks in layer breeds and their crosses ranged between 49.89 ± 0.18 g in IWI strain of WLH (Sreenivas, 2013) to 66.20 g in Dahlem red breed (Singh, 2001). Egg weight at 40 weeks in native breeds x exotic layer breeds also fall within the above range. Broiler breeds or their crosses with native chicken produced eggs which ranged from

Table 4. Average egg weights at 28 weeks (EW28) of age (g) as reported in literature

BREED / VARIETIES	MEAN \pm S.E	AUTHOR (s)
IWH	45.94 \pm 5.65	Chatterjee <i>et al.</i> (2008)
IWI	47.15 \pm 4.94	
IWK	49.61 \pm 7.16	
Control (WLH)	47.05 \pm 6.12	
IWH	46.54 \pm 0.15	Jayalaxmi <i>et al.</i> (2008)
IWI	46.59 \pm 0.11	
IWK	49.07 \pm 0.15	
Control (WLH)	46.41 \pm 0.15	
C1 cross	52.08 \pm 0.29	Niranjan <i>et al.</i> (2008)
C2 cross	50.18 \pm 0.34	
Vanaraja	49.63 \pm 0.27	
Gramapriya	51.76 \pm 0.27	
Naked neck	53.67	Rajkumar <i>et al.</i> (2009)
Aseel (Farm)	42.71 \pm 0.36	Haunshi <i>et al.</i> (2011)
Kadakhnath (K) (Farm)	35.58 \pm 0.34	
Vanaraja	42-44	Rajkumar <i>et al.</i> (2010)
Gramapriya	52-53	
Naked neck (NN) (Farm)	53.20 \pm 0.03	RajKumar <i>et al.</i> (2012d)
Dwarf chicken	46.30 \pm 0.04	Rajkumar <i>et al.</i> (2011a)
Mazandaran Native chicken	46.91	Niknafs <i>et al.</i> (2012)
DW X PB2 CROSS	47.56 \pm 0.74	Rajkumar <i>et al.</i> (2012b)
PB2 X DW CROSS	48.99 \pm 0.55	

(Contd...)

Table 4 (Contd...)

Type-I(F3)	45.9 ± 0.24	Rao <i>et al.</i> (2012a)
Type-II(F3)	45.6 ± 0.23	
IWH	43.81 ± 0.15	Sreenivas (2013)
IWI	44.70 ± 0.17	
IWK	46.77 ± 0.15	
Control (WLH)	45.18 ± 0.18	
RIR ^s	44.98 ± 0.20	Das <i>et al.</i> (2014)
RIR ^c	43.46 ± 0.50	
RIR ^w	44.45 ± 0.67	
CARI-Sonali	46.66 ± 0.33	
CARI-Debendra	46.78 ± 0.59	
PD1×PD4	46.97 ± 0.42	
PD1×PB2	51.01 ± 0.61	
PD1×PD3	49.37 ± 0.57	
PD1×IWI	48.58 ± 0.57	
PD1	47.37 ± 0.01	Padhi <i>et al.</i> (2015a)
PD1 X IWI X PD3	51.25	Padhi <i>et al.</i> (2016)

Table 5. Average egg weights at 40 weeks (EW40) of age (g) as reported in literature

BREED / VARIETIES	MEAN \pm S.E	AUTHOR (s)
Native breeds		
Aseel (Field)	41.00	Singh <i>et al.</i> (2000)
Black Nicobari	44.00 \pm 0.30	Ahlawat and Padhi (2001)
White Nicobari	43.00 \pm 0.70	
Brown Nicobari (BrN)	45.00 \pm 2.00	
Nicobari	42.00 \pm 0.53	
Naked neck (NN)	41.00 \pm 0.33	Padhi <i>et al.</i> (2001)
Frizzle Fowl (FF)	42.00 \pm 0.30	
Aseel (A)	52.70 \pm 0.06	Singh (2001)
Danki	46.16 \pm 1.72	Vij <i>et al.</i> (2006)
Ghagus	40.25 \pm 2.39	
Kalasthi	42.91 \pm 1.94	
Kadaknath	43.20	Niranjan <i>et al.</i> (2008a)
Aseel	46.47	
Nacked neck	59.96	Rajkumar <i>et al.</i> (2009)
Miri type	38.67 \pm 0.31	Haunshi <i>et al.</i> (2009)
Aseel (Farm)	45.80 \pm 0.49	Haunshi <i>et al.</i> (2011)
Kadaknath (K) (Farm)	39.92 \pm 0.38	
Naked neck (NN)	60.61 \pm 0.04	Rajkumar <i>et al.</i> (2012d)
Dwarf chicken	55.28 \pm 0.03	Rajkumar <i>et al.</i> (2011a)
Aseel	42.38 \pm 2.34	Jha and Prasad (2013)
Hazra	51.24 \pm 1.84	Jha <i>et al.</i> (2013a)
Aseel (Farm)	42.58 \pm 2.24	
Kadaknath (K) (Farm)	46.23 \pm 2.31	

(Contd...)

Table 5 (Contd...)

Dahlem Red	55.87 ± 2.24	Jha <i>et al.</i> (2013b)
Dahlem Red X Desi	51.26 ± 2.35	
Dahlem Red	48.60 ± 3.55	Kalita <i>et al.</i> (2015)
Exotic layer breeds and their crosses		
WLH	50.00 ± 1.00	Ahlawat and Padhi (2001)
WLH	52.93 ± 0.08	Kataria and Johari (2001)
CARI – Gold	52.70	
RIR	54.72 ± 0.12	Singh (2001)
Dahlem Red	66.20	
RIR	54.32 ± 0.00	Jilani <i>et al.</i> (2005)
IWH	49.26 ± 5.60	Chatterjee <i>et al.</i> (2008)
IWI	49.75 ± 5.30	
IWK	53.79 ± 7.29	
Control (WLH)	49.91 ± 7.64	
IWH	50.54 ± 0.14	Jayalaxmi <i>et al.</i> (2008)
IWI	50.78 ± 0.12	
IWK	54.23 ± 0.17	
Control (WLH)	51.50 ± 0.15	
WLH (IWN Strain)	54.04 ± 0.02	Anees <i>et al.</i> (2010)
WLH (IWH strain)	50.54 ± 0.14	Jayalaxmi <i>et al.</i> (2010)
Dahlem Red	56.25	Prasad <i>et al.</i> (2012)
IWH	50.22 ± 0.18	Sreenivas (2013)
IWI	49.89 ± 0.18	
IWK	53.13 ± 0.17	
Control (WLH)	50.81 ± 0.20	

(Contd...)

Table 5 (Contd...)

RIR ^s	51.75 ± 0.19	Das <i>et al.</i> (2014)
RIR ^c	50.45 ± 0.47	
RIR ^w	51.23 ± 0.62	
CARI-Sonali	53.46 ± 0.31	
CARI-Debendra	53.52 ± 0.55	
WLH (WL)	53.41 ± 3.89	Yi <i>et al.</i> (2014)
Dwarf (DW)	51.71 ± 4.14	
RIR	50.76 ± 0.90	Rayan <i>et al.</i> (2015)
Native breed crossed with exotic layer breeds		
BrN × WLH	47.00 ± 0.70	Ahlawat and Padhi (2001)
WLH × BrN	49.00 ± 0.89	
DR × A	56.40	Singh (2001)
A × DR	53.80	
CARI – Nirbheek	56	Singh <i>et al.</i> (2004)
HIT – CARI	58	
UP – CARI	59	
CARI – Shyama	54	
CARI – Nirbheek (Field)	53	Singh (2005)
CARI – Nirbheek (Farm)	54	
HIT – CARI (Field)	59	
HIT – CARI (Farm)	61	
UP – CARI (Field)	58	
UP – CARI (Farm)	60	
CARI – Shyama (Field)	52.50	
CARI – Shyama (Farm)	53.00	

(Contd...)

Table 5 (Contd...)

CARI – Nirbheek	53.00	Kumar <i>et al.</i> (2008a)
CARI – Shyama	52.50	
Rajasri	55.00	Rao <i>et al.</i> (2008)
CARI – Shyama (Farm)	53.32 ± 0.38	Malik <i>et al.</i> (2009)
CARI – Nirbheek	53.78 ± 0.33	Malik and Singh (2010)
A × WLH (Farm)	42.20 ± 0.33	Rao <i>et al.</i> (2010)
A × Synthetic population (Farm)	50.31 ± 0.45	
Rajasri	50.66 ± 0.15	Rao <i>et al.</i> (2012)
Type-I(F3)	49.7 ± 0.36	Rao <i>et al.</i> (2012a)
Type-II(F3)	49.8 ± 0.18	
Rajasri	48	Naga Raja Kumari <i>et al.</i> (2014)
Native breed crossed with exotic broiler breeds		
NN × Synthetic Broiler (SB)	52.00 ± 0.40	Padhi <i>et al.</i> (2001)
SB × FF	50.00 ± 0.42	
DW X PB2 Cross	73.56 ± 3.52	Rajkumar <i>et al.</i> (2012b)
DW X PB2 Cross	78.74 ± 2.21	
Bahig	48.15 ± 0.76	Rayan <i>et al.</i> (2015)
Matrouh	47.23 ± 0.84	
Exotic breed / synthetic genotypes with broiler parent inheritance		
Vanaraja	55 – 63	Ayyagari (2001)
Krishna – J	48.30	Khan (2001)
Giriraja	48 – 52	Ramappa (2001)
Vanaraja	46 – 55	Bhattacharya <i>et al.</i> (2005)
Vanaraja	58.00	Kumar <i>et al.</i> (2005)
CARI – Debendra	39.10 ± 0.30	Singh <i>et al.</i> (2005)
Vanaraja	51.60	Bhat <i>et al.</i> (2008)

(Contd...)

Table 5 (Contd...)

C1 cross	58.58 ± 0.29	Niranjan <i>et al.</i> (2008b)
C2 cross	57.35 ± 0.33	
Gramapriya	57.43 ± 0.27	
Vanaraja	57.06 ± 0.27	
Vanaraja	55.42 ± 0.46	Haunshi <i>et al.</i> (2009)
Gramapriya	57.22 ± 0.72	
Vanaraja	46.6 ± 0.51	Ramana <i>et al.</i> (2010)
Vanaraja	59.5 ± 3.25	Kalita <i>et al.</i> (2012)
Gramapriya	50.04	Bhat <i>et al.</i> (2012)
Gramapriya	52.00 ± 1.50	Prakash <i>et al.</i> (2012)
Gramapriya	51.86	Rajkumar <i>et al.</i> (2012)
PD1	53.69 ± 0.01	Padhi and Chatterjee (2012)
Gramapriya	49	Pathak and Nath (2013)
Vanaraja	51	
Vanaraja	53.98 ± 1.24	Jha and Prasad (2013)
Gramapriya	54.23 ± 2.34	
PB-2	55.93 ± 0.32	Rajaravindra <i>et al.</i> (2015)
Vanaraja	51.08 ± 0.36	Deka <i>et al.</i> (2014)
Gramapriya	51.27 ± 0.57	Hajra <i>et al.</i> (2014)
Vanaraja	51.80 ± 0.44	
Vanaraja	53.07 ± 0.24	Islam <i>et al.</i> (2014)
PD1 x PD4	50.70 ± 0.96	Padhi <i>et al.</i> (2014)
PD1	56.49 ± 0.02	Padhi <i>et al.</i> (2015)
PD1	54.61 ± 0.01	Padhi <i>et al.</i> (2015a)

(Contd...)

Table 5 (Contd...)

PD1×PD4	54.52 ± 0.59	Padhi <i>et al.</i> (2015b)
PD1×PB2	56.81 ± 0.60	
PD1×PD3	53.82 ± 0.55	
PD1×IWI	54.68 ± 0.59	
PD1 X IWI X PD3	57.14	Padhi <i>et al.</i> (2016)
Vanaraja	57.32 ± 0.12	Sankhyan and Thakur (2016)

46.00 to 59.5 ± 3.25 g (Bhattacharya *et al.*, 2005; Kalita *et al.*, 2012).

2.3 FERTILITY AND HATCHABILITY

Fertility and hatchability of eggs greatly influence the profitability of poultry breeding organization. Various genetic and non-genetic factors like genotype / breed, age of birds, type of breeding, skill of the employers involved in artificial insemination and maintenance of hatchery equipment determine the fertility and hatchability rates.

2.3.1 Fertility

Fertility and hatchability values in different genetic groups of chicken, as reported in the literature are presented in Table (6).

The mean per cent fertility reported in the literature had a wide range. Average per cent fertility ranged from 70.44 in Kadaknath (Bhardwaj *et al.*, 2006) to 90.63 in Naked Neck (Rajkumar *et al.*, 2015) with respect to native chicken. In exotic birds, it ranged from 52.96 ± 4.22 in Golden Bantam (Pandian *et al.*, 2009) to 95.85 ± 0.22 in IWN strain of White Leghorn (WLH) (Narayanankutty *et al.*, 2008). In crossbreds, it ranged from 55 in WLH X Aseel cross (Ahmed *et al.*, 2012) to 98.04 in Colour broiler \times WLH (Ravi *et al.*, 2008).

Table 6. Fertility and hatchability values in different genetic groups of chicken as reported in the literature

Breed	Fertility (%)	Hatchability (%) on		Reference
		Total egg set	Fertile egg set	
Aseel	84.28	73.97	85.11	Singh <i>et al.</i> (2000)
Danki	-	71.93	-	Vij <i>et al.</i> (2006)
Kalasthi	-	72.14	-	
Ghagus	-	81.36	-	
Kadaknath	70.44	44.75	57.75	
Aseel	73.22	41.90	58.00	Bhardwaj <i>et al.</i> (2006)
RIR	75.21	38.01	50.39	
Brown Cornish	71.92	35.54	49.41	
Kadaknath × Brown Cornish	62.61	51.43	78.82	
Brown Cornish × Kadaknath	71.35	55.91	79.13	
Aseel × RIR	72.43	57.25	78.33	
RIR × Aseel	76.39	64.91	84.93	
Tellicherry	86.44	61.02	70.59	
Colour broiler × RIR	96.88	93.06	96.06	Mhatre <i>et al.</i> (2008)
RIR × Colour broiler	96.03	92.80	96.64	
Colour broiler × Aseel peela	97.09	94.18	97.00	
Colour broiler × Aseel kala	96.93	94.57	97.57	
WLH (IWN)	95.85 ± 0.22	77.79 ± 0.45	81.06 ± 0.43	Narayanankutty <i>et al.</i> (2008)
WLH (IWP)	93.62 ± 0.27	70.52 ± 0.50	75.33 ± 0.49	
PD-1 line	82.16	74.22	90.51	Niranjan <i>et al.</i> (2008)

(Contd...)

Table 6 (Contd...)

Colour broiler × Kadaknath	96.49	92.81	96.18	Ravi <i>et al.</i> (2008)
Colour broiler × WLH	98.04	96.46	98.39	
Colour broiler × Naked neck	96.64	92.89	96.13	
Colour broiler × Frizzle	96.80	92.01	95.05	
Tripura black	81.00	67.00	62.72	Malik <i>et al.</i> (2009a)
CARI <i>Shyama</i>	79.49	49.86	62.72	Malik <i>et al.</i> (2009b)
IC3- meat line	84.66	78.39	-	Murthy <i>et al.</i> (2009)
UM1- meat line	78.77	84.08	-	
PB1- meat line	90.66	87.30	-	
NG- meat line	91.66	84.09	-	
English Bantam	81.39 ± 3.18	65.24 ± 3.99	79.90 ± 3.62	Pandian <i>et al.</i> (2009)
Cochin Bantam	83.59 ± 3.13	75.31 ± 3.83	89.59 ± 2.90	
Golden Bantam	52.96 ± 4.22	44.46 ± 3.61	87.77 ± 3.28	
Japanese Bantam	83.41 ± 2.41	72.23 ± 3.68	86.41 ± 3.60	
Dwarf	83.24 ± 3.14	75.24 ± 4.18	90.40 ± 2.14	Rajkumar <i>et al.</i> (2010a)
CARI <i>Nirbheek</i>	80.36	54.91	68.32	Malik and Singh (2010)
Blackrock	87.96	63.52	72.21	Kumar <i>et al.</i> (2011)
<i>Gramapriya</i>	87.22	70.93	81.32	
<i>Vanaraja</i>	87.78	71.67	81.65	
Dahlem Red (75%) × Tripura Black (25%)	79.98	70.16	87.72	Malik <i>et al.</i> (2011a)
Coloured broiler sire line	75.10	60.20	80.16	Malik <i>et al.</i> (2011b)
Dwarf	82.14 ± 2.14	83.24 ± 2.82	96.28 ± 1.19	Rajkumar <i>et al.</i> (2011a)

(Contd...)

Table 6 (Contd...)

Naked neck	81.09 ± 2.16	75.46 ± 2.51	82.14 ± 3.01	Rajkumar <i>et al.</i> (2011)
Naked neck	86.64	70.26	80.24	Saxena <i>et al.</i> (2011)
Naked neck X WLH	71.16	46.78	65.64	Singh <i>et al.</i> (2011a)
Frizzle X WLH	78.79	59.65	75.70	
WLH X NN	90.6	-	85.3	Ahmed <i>et al.</i> (2012)
WLH X Fayumi	84.6	-	84.6	
WLH X RIR	87	-	83.9	
WLH X Aseel	55	-	57.5	
WLH X Desi	82.6	-	76.2	
Aseel	86.96	70.74	81.21	Haunshi <i>et al.</i> (2012)
Kadakhnath	85.15	77.94	90.30	
Vanaraja	83.36 ± 5.32	62.02 ± 4.39	79.23 ± 5.31	Kalita <i>et al.</i> (2012)
Coloured broilers male line × Tripura black	81.40	70.47	86.57	Malik <i>et al.</i> (2012)
Gramapriyamale Line	87.65	91.12	80.0	Rajkumar <i>et al.</i> (2012a)
PB-2 × Dwarf	95.28 ± 2.98	91 ± 4.19	28 ± 2.21	Rajkumar <i>et al.</i> (2012b)
Dwarf × PB-2	93.14 ± 4.16	86.27 ± 5.21	95.02 ± 3.01	
Dwarf dam line	90.65	84.95	92.57	Rajkumar <i>et al.</i> (2012c)
Normal broiler Female line (PB2)	79.1	68.63	87.54	
Synthetic coloured broiler (PB-1)	75.28 to 90.24	68.89 to 83.17	90.17 to 92.16	Singh <i>et al.</i> (2012)
Rajasri	84	-	75	Rao <i>et al.</i> (2012)
Gramapriya	80.34	65.77	89.21	Patel <i>et al.</i> (2013)

(Contd...)

Table 6 (Contd...)

FF	85.00 ± 3.91	-	-	Basant <i>et al.</i> (2013)
RR	85.59 ± 4.33	-	-	
FR	82.04 ± 3.82	-	-	
RF	83.99 ± 4.51	-	-	
RIR ^s	75.86	57.46	75.65	Das <i>et al.</i> (2014)
RIR ^c	79.03	68.51	86.62	
RIR ^w	79.34	67.80	85.27	
CARI-Sonali	70.83	55.58	78.44	
CARI-Debendra	60.64	53.09	87.54	
Vanaraja	91.28 ± 8.43	89.78 ± 6.32	-	Islam <i>et al.</i> (2014)
Rajasri	-	85 - 89%	-	Naga Raja Kumari <i>et al.</i> (2014)
Dahlem Red	93.69 ± 4.76	78.23 ± 3.56	87.90 ± 4.39	Kalita <i>et al.</i> (2015)
PD1	90.46 ± 0.02	83.20 ± 0.02	91.38 ± 0.02	Padhi <i>et al.</i> (2015a)
Dahlem Red	92.47	84.78	-	Rayan <i>et al.</i> (2015)
Bahig	92.27	94.39	-	
Matrouh	84.24	87.53	-	
Naked Neck	90.63	68.8	79.87	Rajkumar <i>et al.</i> (2015)
PB-2	79.34	70.89	94.00	
Dahlem Red	92.90	83.33	91.50	
Vanaraja	86.82 ± 2.26	74.58 ± 1.16	-	Sankhyan and Thakur (2016)

2.3.2 Hatchability

Average per cent hatchability on TES in native chicken ranged from 41.90 in Aseel (Bhardwaj *et al.*, 2006) to 83.24 ± 3.14 in Dwarf chicken (Rajkumar *et al.*, 2010a), while in exotic breeds, it ranged from 35.54 in Brown Cornish (Bhardwaj *et al.*, 2006) to 77.79 ± 0.45 in IWN strain of WLH. In crossbreds, it ranged from 49.86 in CARI *Shyama* (Malik *et al.*, 2009b) to 96.46 in Colour broiler \times WLH cross (Ravi *et al.*, 2008).

Average per cent hatchability on FES ranged from 57.75 in Kadaknath (Bhardwaj *et al.*, 2006) to 96.28 ± 1.19 in Dwarf chicken (Rajkumar *et al.*, 2011a) with respect to native birds. While in exotic birds it ranged from 49.41 in Brown Cornish (Bhardwaj *et al.*, 2006) to 89.59 ± 2.90 in Cochin bantam (Pandian *et al.*, 2009). In case of crossbreds it ranged from 28 ± 2.21 in PB-2 \times Dwarf cross (Rajkumar *et al.*, 2012b) to 98.39 in Colour broiler \times WLH cross (Ravi *et al.*, 2008).

2.4 Egg quality traits at 40 weeks of age

The means and standard errors of different egg quality traits in various breeds /strains as reported in the literature are presented in the Table (7). The haugh unit score in case of native chicken ranged from 67.30 in Kadaknath (Parmar *et al.*, 2006) to 75.43 ± 0.84 in Aseel (Haunshi *et al.*, 2011); in exotic breeds, it ranged from 65.38 ± 0.92 in IWK strain (Sreenivas, 2013) to 92.00 ± 0.19 in WLH (Rath *et al.*, 2015) and among crosses, it ranged from 72.51 in Van \times WN (Kundu *et al.*, 2015) to 91.12 in BrN \times Van (Kundu *et al.*, 2015) WN (Kundu *et al.*, 2015) to 91.12 in BrN \times Van.

Table 7. Mean values of various egg quality parameters in different genetic groups of chicken as reported in the literature

BREED / VARIETIES	Haugh unit	Albmen index	Yolk index	Shell thickness (mm)	Shell weight	Yolk colour	Shell colour	AUTHOR (s)
Kadaknath (Field)	67.30	0.055	0.36	0.31	-	-	-	Parmar <i>et al.</i> (2006)
Nacked neck	-	0.101	0.34	-	6.63	-	-	Chatterjee <i>et al.</i> (2007)
White Nicobari	-	0.112	0.34	-	5.96	-	-	
Brown Nicobari	-	0.122	0.37	-	6.05	-	-	
Black Nicobari	-	0.107	0.43	-	6.76	-	-	
Cross 1 (C1)	78.9	-	0.37	0.40	5.51	7.98	-	Niranjan <i>et al.</i> (2008c)
Cross 2 (C2)	76.6	-	0.38	0.40	5.49	7.63	-	
Vanaraja (C3)	77.1	-	0.36	0.38	5.46	7.81	-	
Gramapriya (C4)	75.4	-	0.48	0.38	4.99	7.86	-	
CARI-Shyama	81.70 ± 1.19	0.057 ± 0.001	0.42 ± 0.004	0.31 ± 0.001	-	-	-	Malik <i>et al.</i> (2009)
Naked neck	72.40	-	36.07	0.372	5.52	6.99	-	Rajkumar <i>et al.</i> (2009)

(Contd...)

Table 7 (Contd...)

Miri Type	69.94 ± 1.54	0.060 ± 0.003	0.36 ± 0.012	0.386 ± 0.012	-	-	Creamy to light brown	Haunshi <i>et al.</i> (2009)
Gramapriya	69.10 ± 1.41	0.0714 ± 0.003	0.37 ± 0.006	0.319 ± 0.005	-	-	Brown to Dark Brown	
Vanaraja	67.41 ± 2.71	0.072 ± 0.002	0.35 ± 0.006	0.352 ± 0.006	-	-	Brown	
Aseel	75.43 ± 0.84	0.076 ± 0.002	0.395 ± 0.006	-	4.94 ± 0.08	-	-	Haunshi <i>et al.</i> (2011)
Kadaknath	74.99 ± 0.69	0.072 ± 0.002	0.367 ± 0.008	-	4.34 ± 0.04	-	-	
Vanaraja	-	0.16 ± 0.01	0.59 ± 0.02	-	-	-	-	Kalitha <i>et al.</i> (2012)
Vanaraja	71.26±0.65	6.81±0.14 (%)	36.12±0.56	0.35±0.007	-	-	Light brown	Jha and Prasad (2013)
Gramapriya	72.27±0.64	6.97±0.13 (%)	36.68±0.56	0.32 ± 0.00	-	-	Brown	
Aseel	69.94±0.68	6.25±0.14 (%)	35.84±0.57	0.36 ± 0.00	-	-	Creamy Brown	
Hazra	72.89 ± 0.65	6.86 ± 0.14(%)	36.12 ± 0.56	0.35 ± 0.007	-	-	-	Jha <i>et al.</i> (2013a)
Aseel	71.23 ± 0.68	6.25 ± 0.14(%)	35.84 ± 0.57	0.36 ± 0.008	-	-	-	
Kadaknath	72.57 ± 0.64	6.97 ± 0.13(%)	36.68 ± 0.56	0.32 ± 0.007	-	-	-	

(Contd...)

Table 7 (Contd...)

IWH	72.99 ± 1.03	0.072 ± 0.00	0.343 ± 0.00	0.336 ± 0.00	4.32 ± 0.05	-	-	Sreenivas (2013)
IWI	80.98 ± 1.01	0.09 ± 0.00	0.35 ± 0.00	0.376 ± 0.00	4.77 ± 0.05	-	-	
IWK	65.38 ± 0.92	0.056 ± 0.00	0.341 ± 0.00	0.362 ± 0.00	5.12 ± 0.05	-	-	
Control (WLH)	74.85 ± 0.92	0.077 ± 0.002	0.343 ± 0.003	0.365 ± 0.003	4.72 ± 0.05	-	-	
Fayoumi	-	-	-	0.36 ± 0.04	5.63 ± 0.76	-	-	Regassa <i>et al.</i> (2013)
Gramapriya (Deep litter)	-	0.15	0.45	0.36	-	-	-	Patel <i>et al.</i> (2013)
Gramapriya (Semi-Intensive)	-	0.15	0.44	0.35	-	-	-	
Gramapriya (Field)	-	0.13	0.45	0.34	-	-	-	
Gramapriya	-	-	-	-	-	-	Tinted	Pathak and Nath. (2013)
Vanaraja	-	-	-	-	-	-	Tinted	
PB-2	77.17 ± 0.82	0.081 ± 0.002	0.40 ± 0.003	0.364 ± 0.003	4.91 ± 0.04	7.91 ± 0.06	-	Rajaravindra <i>et al.</i> (2015)
Dahlem Red	79.23 ± 1.45	0.076 ± 0.002	0.372 ± 0.009	0.301 ± 0.005	-	-	-	Kalitha <i>et al.</i> (2015)

(Contd...)

Table 7 (Contd...)

Van	74.33	-	-	0.38 ± 0.04	4.64 ± 0.20	-	-	Kundu <i>et al.</i> (2015)
WN	81.23	-	-	0.34 ± 0.01	5.95 ± 0.01	-	-	
BN	747.24	-	-	0.36 ± 0.02	6.05 ± 0.23	-	-	
BrN	69.64	-	-	0.36 ± 0.01	5.40 ± 0.09	-	-	
BN \times Van	93.22	-	-	0.32 ± 0.03	7.19 ± 0.71	-	-	
Van \times BN	75.02	-	-	0.33 ± 0.03	5.82 ± 0.03	-	-	
Van \times BrN	90.99	-	-	0.35 ± 0.01	6.25 ± 0.21	-	-	
WN \times Van	80.27	-	-	0.42 ± 0.02	5.57 ± 0.25	-	-	
BrN \times Van	91.12	-	-	0.31 ± 0.01	5.73 ± 0.16	-	-	

(Contd...)

Table 7 (Contd...)

Van × WN	72.51	-	-	0.31 ± 0	6.64 ± 0.33	-	-	
RIR	-	-	-	0.38 ± 0.01	5.60 ± 0.15	-	-	Rayan <i>et al.</i> (2015)
Bahig	-	-	-	0.37 ± 0.01	5.31 ± 0.11	-	-	
Matrouh	-	-	-	0.38 ± 0.01	5.72 ± 0.15	-	-	
PD1	73.46 ± 1.45	0.06 ± 0.003	0.40 ± 0.003	0.33 ± 0.004	-	6.23 ± 0.19	-	Padhi <i>et al.</i> (2015)
WLH	92.00 ± 0.19	0.09 ± 0.05	0.40 ± 0.10	0.32 ± 0.00	6.00 ± 0.03	-	-	Rath <i>et al.</i> (2015)

The albumen index value was found to range from a low value of 0.055 in Kadaknath (Parmar *et al.*, 2006) to a high value of 0.16 in Vanaraja (Kalita *et al.*, 2012) while the Yolk Index ranged from 0.34 ± 0.01 in Naked neck and White Nicobari breeds (Chatterjee *et al.*, 2007) to 0.42 ± 0.004 in CARI-Shyama (Malik *et al.*, 2009).

Shell thickness (mm) varied from 0.301 ± 0.005 in Delham Red (Kalita *et al.*, 2015) to 0.42 ± 0.02 in WN X VAN (Kundu *et al.*, 2015) and shell weight (g) ranged from 4.32 ± 0.05 in IWH strain (Sreenivas, 2013) to 6.76g in White Nicobari (Chatterjee *et al.*, 2007).

Yolk colour was found to be ranging from 6.23 ± 0.19 in PD1 (Padhi *et al.*, 2015) to 7.98 in Cross 1 (Niranjan *et al.* 2008c).

Wide variation was reported in shell colour among different breeds / genotypes. Haunshi *et al.* (2009) reported creamy to light brown colour in Miri type chicken, brown to dark brown colour in Gramapriya birds and brown colour in Vanaraja birds.

2.5 GENETIC PARAMETERS

Heritability estimates are population and time specific and the magnitude of h^2 given indicates type of the gene action and the possible response for selection of the trait under study. While genetic correlations indicate the possible response in correlated traits and are helpful in designing breeding strategies.

2.5.1 Heritability estimates of body weight

Padhi and Chatterjee (2012) reported that the heritability estimates from sire, dam and sire + dam components were 0.69 ± 0.26 , 0.11 ± 0.26 and 0.40 ± 0.19 respectively for body weight at 32 weeks of age in PD1 (Vanaraja male line).

The heritability estimates for body weight at 40 weeks of age based on sire, dam and S+D components in various breeds / varieties / strains as reported in the literature are presented in the Table (8).

The h^2_s estimate for body weight at 40 weeks ranged from 0.055 ± 0.198 in IWH (Jayalaxmi *et al.*, 2008) to 0.62 ± 0.25 in PD1 (Padhi and Chatterjee, 2012) and h^2_D ranged from 0.02 ± 0.17 in IWH (Chatterjee *et al.*, 2008) to 0.658 ± 0.192 , While $h^2_{(S+D)}$ ranged from 0.01 ± 0.14 in PD1 (Padhi *et al.*, 2015a) to 0.444 ± 0.106 in IWK (Jayalaxmi, 2008).

Table 8. Heritability estimates of body weights at 40 weeks of age in chicken as reported in literature

Breed/Strain	h^2_s	h^2_D	h^2_{s+D}	Reference
IWH	0.13 ± 0.11	0.02 ± 0.17	0.08 ± 0.10	Chatterjee <i>et al.</i> (2008)
IWI	0.12 ± 0.11	0.25 ± 0.12	0.19 ± 0.09	
IWK	0.21 ± 0.13	0.26 ± 0.18	0.23 ± 0.11	
Control(WLH)	0.21 ± 0.09	0.34 ± 0.11	0.06 ± 0.08	
RIR	-	-	0.40 ± 0.12	Jilani <i>et al.</i> (2007)
IWH	0.055 ± 0.198	0.658 ± 0.192	0.357 ± 0.095	Jayalaxmi (2008)
IWI	0.164 ± 0.098	0.231 ± 0.137	0.198 ± 0.068	
IWK	0.484 ± 0.186	0.403 ± 0.191	0.444 ± 0.106	
Control(WLH)	0.233 ± 0.133	0.060 ± 0.165	0.146 ± 0.076	
WLH	-	-	0.146 ± 0.076	Jayalaxmi <i>et al.</i> (2011)
Dwarf chicken	0.31 ± 0.21	0.24 ± 0.32	0.27 ± 0.17	Rajkumar <i>et al.</i> (2011a)
Nacked neck	0.17 ± 0.30	0.43 ± 0.34	0.31 ± 0.24	RajKumar <i>et al.</i> (2012d)
PD1	0.62 ± 0.25	0.26 ± 0.27	0.44 ± 0.19	Padhi and Chatterjee (2012)
IWH	0.251 ± 0.146	0.140 ± 0.181	0.196 ± 0.120	Sreenivas (2013)
IWI	0.330 ± 0.179	0.513 ± 0.222	0.421 ± 0.145	
IWK	0.411 ± 0.211	0.416 ± 0.223	0.414 ± 0.157	
Control(WLH)	0.050 ± 0.136	0.071 ± 0.242	0.060 ± 0.145	
PD1	0.04 ± 0.21	0.34 ± 0.38	0.19 ± 0.024	Padhi <i>et al.</i> (2015)
PD1	-	0.06 ± 0.24	0.01 ± 0.14	Padhi <i>et al.</i> (2015a)

2.5.2 Heritability estimates of age at first egg

The heritability estimates for age at first egg based on sire, dam and S+D components in various breeds / varieties / strains as reported in the literature are presented in the Table (9).

Heritability estimates for age at first egg observed in the literature were low to medium in magnitude. Heritability estimates of AFE based on sire component ranged from 0.01 ± 0.07 in PD1 (Padhi and Chatterjee 2012) to 0.33 ± 0.16 in IWI strain of WLH (Chatterjee *et al.*, 2008). The heritability estimates based on dam component ranged from 0.039 ± 0.173 in IWK (Jayalaxmi, 2008) to 0.49 ± 0.41 in PD1 (Padhi *et al.*, 2015) and estimates based on sire + dam component varied from 0.04 ± 0.14 in PD1 (Padhi *et al.*, 2015a) to 0.55 in Dwarf chicken (Yi *et al.*, 2014).

2.5.3 Heritability estimates of egg weight at 28 weeks

The heritability estimates for egg weight at 28 weeks of age based on sire, dam and S+D components in various breeds / varieties / strains as reported in the literature are presented in the Table (10). Heritability estimates of sire component for egg weight at 28 weeks ranged from 0.011 ± 0.09 in IWH (Jayalaxmi, 2008) to 0.698 ± 0.19 in IWI (Jayalaxmi, 2008) and of dam component ranged from 0.01 ± 0.12 in WLH control (Chatterjee *et al.*, 2008) to 0.508 ± 0.19 in IWH (Jayalaxmi, *et al.*, 2010) and of S+D component ranged from 0.058 ± 0.07 in WLH control population to 0.496 ± 0.090 in IWI (Jayalaxmi, 2008).

Table 9. Heritability estimates of age at first egg as reported in literature

Breed/Strain	h^2_s	h^2_D	h^2_{s+D}	Reference
IWH	0.22 ± 0.13	0.11 ± 0.18	0.16 ± 0.11	Chatterjee <i>et al.</i> (2008)
IWI	0.33 ± 0.16	0.38 ± 0.16	0.36 ± 0.11	
IWK	0.28 ± 0.14	0.14 ± 0.17	0.21 ± 0.11	
Control (WLH)	0.19 ± 0.12	0.06 ± 0.15	0.12 ± 0.09	
RIR	-	-	0.50 ± 0.13	Jilani <i>et al.</i> (2007)
IWH	0.049 ± 0.112	0.363 ± 0.185	0.182 ± 0.082	Jayalaxmi <i>et al.</i> (2008)
IWI	0.083 ± 0.101	0.274 ± 0.139	0.229 ± 0.071	
IWK	-	0.039 ± 0.173	0.020 ± 0.067	
Control (WLH)	0.039 ± 0.093	0.170 ± 0.170	0.104 ± 0.072	
Dwarf chicken	0.18 ± 0.21	0.56 ± 0.38	0.37 ± 0.34	Rajkumar <i>et al.</i> (2011a)
PD1	0.01 ± 0.07	0.55 ± 0.33	0.28 ± 0.20	Padhi and Chatterjee (2012)
Mazandaran Native chicken	-	-	0.36 ± 0.01	Niknafs <i>et al.</i> (2012)
IWH	0.141 ± 0.110	0.128 ± 0.165	0.007 ± 0.103	Sreenivas (2013)
IWI	0.016 ± 0.096	0.123 ± 0.111	0.054 ± 0.119	
IWK	0.010 ± 0.099	0.215 ± 0.194	0.103 ± 0.113	
Control (WLH)	0.131 ± 0.041	0.232 ± 0.158	0.147 ± 0.096	
Esfahan native	-	-	0.15 ± 0.01	Yousefi Zonuz <i>et al.</i> (2013)
WLH	-	-	0.32	Yi <i>et al.</i> (2014)
Dwarf (DW)	-	-	0.55	
PD1	-	0.49 ± 0.41	0.20 ± 0.24	Padhi <i>et al.</i> (2015)
PD1	-	0.10 ± 0.13	0.04 ± 0.14	Padhi <i>et al.</i> (2015a)

Table 10. Heritability estimates of egg weights at 28 weeks of age as reported in literature

Breed/Strain	h^2_s	h^2_D	h^2_{S+D}	Reference
IWH	0.31 ± 0.15	0.19 ± 0.18	0.25 ± 0.15	Chatterjee <i>et al.</i> (2008)
IWI	0.52 ± 0.18	0.11 ± 0.12	0.32 ± 0.13	
IWK	0.51 ± 0.18	0.05 ± 0.14	0.23 ± 0.13	
Control (WLH)	0.67 ± 0.27	0.01 ± 0.12	0.23 ± 0.15	
IWH	0.011 ± 0.09	0.508 ± 0.19	0.260 ± 0.09	Jayalaxmi <i>et al.</i> (2008)
IWI	0.698 ± 0.19	0.294 ± 0.140	0.496 ± 0.090	
IWK	0.199 ± 0.14	0.192 ± 0.18	0.195 ± 0.08	
Control (WLH)	0.115 ± 0.11	-	0.058 ± 0.07	
Nacked neck	0.64 ± 0.22	-	0.17 ± 0.23	RajKumar <i>et al.</i> (2012d)
Dwarf chicken	0.36 ± 0.38	0.31 ± 0.42	0.33 ± 0.26	Rajkumar <i>et al.</i> (2011a)
Mazandaran Native chicken	-	-	0.32 ± 0.01	Niknafs <i>et al.</i> (2012)
IWH	0.109 ± 0.125	0.293 ± 0.201	0.201 ± 0.159	Sreenivas (2013)
IWK	0.360 ± 0.173	0.187 ± 0.052	0.154 ± 0.151	
Control (WLH)	0.207 ± 0.149	0.219 ± 0.159	0.171 ± 0.024	
PD1	0.07 ± 0.12	-	-	Padhi <i>et al.</i> (2015)

2.5.4 Heritability estimates of egg weight at 40 weeks

The heritability estimates for egg weight at 40 weeks of age based on sire, dam and S+D components in various breeds / varieties / strains as reported in the literature are presented in the Table (11).

Heritability estimates of sire component for egg weight at 40 weeks ranged from 0.10 ± 0.26 in Dwarf population (Rajkumar *et al.*, 2011a) to 0.825 ± 0.275 in WLH control population (Sreenivas, 2013) and of dam component ranged from 0.06 ± 0.10 in IWI (Chatterjee *et al.*, 2008) to 0.608 ± 0.19 in IWH (Jayalaxmi, 2008) and of S+D component ranged from 0.101 ± 0.156 in IWH (Sreenivas, 2013) to 0.419 ± 0.188 in WLH control population (Sreenivas, 2013).

2.5.5 Heritability estimates of egg production up to 40 weeks of age

The heritability estimates for egg production up to 40 weeks of age based on sire, dam and S+D components in various breeds / varieties / strains as reported in the literature are presented in the Table (12).

The reports on heritability estimates of egg production up to 40 weeks of age based on sire, dam and S+D component of variance were low to moderate magnitude. The reported estimates based on sire component ranged from 0.01 ± 0.12 in PD1 (Chatterjee *et al.*, 2008) to 0.43 ± 0.18 in WLH control population (Padhi *et al.*, 2015a), while heritability estimates based on dam component ranged from 0.06 ± 0.24 in PD1 (Padhi *et al.*, 2015a) to 0.41 ± 0.39 in PD1 (Padhi *et al.*, 2015) and values of

Table 11. Heritability estimates of egg weights at 40 weeks of age as reported in literature

Breed/Strain	h^2_s	h^2_D	h^2_{s+D}	Reference
IWH	0.54 ± 0.19	0.15 ± 0.16	0.34 ± 0.16	Chatterjee <i>et al.</i> (2008)
IWI	0.55 ± 0.17	0.06 ± 0.10	0.25 ± 0.11	
IWK	0.73 ± 0.23	0.09 ± 0.14	0.41 ± 0.15	
Control(WLH)	0.80 ± 0.26	0.28 ± 0.15	0.55 ± 0.17	
IWH	0.225 ± 0.11	0.608 ± 0.19	0.417 ± 0.09	Jayalaxmi <i>et al.</i> (2008)
IWI	0.513 ± 0.161	-	0.257 ± 0.073	
IWK	0.465 ± 0.18	0.265 ± 0.18	0.365 ± 0.10	
Control(WLH)	0.297 ± 0.14		0.149 ± 0.07	
Nacked neck	0.16 ± 0.32	0.55 ± 0.32	0.35 ± 0.28	RajKumar <i>et al.</i> (2012d)
Dwarf chicken	0.10 ± 0.26	0.38 ± 0.37	0.24 ± 0.28	Rajkumar <i>et al.</i> (2011a)
PD1	0.43 ± 0.20	0.24 ± 0.29	0.33 ± 0.20	Padhi and Chatterjee (2012)
IWH	0.106 ± 0.017	0.186 ± 0.196	0.101 ± 0.156	Sreenivas (2013)
IWI	0.218 ± 0.146	0.275 ± 0.210	0.246 ± 0.161	
IWK	0.120 ± 0.033	0.187 ± 0.042	0.145 ± 0.037	
Control(WLH)	0.825 ± 0.275	0.192 ± 0.013	0.419 ± 0.188	
WLH	-	-	0.44	Yi <i>et al.</i> (2014)
Brown Egg Dwarf	-	-	0.35	
WLH	0.443 ± 0.160	0.277 ± 0.23	0.360 ± 0.131	Rath <i>et al.</i> (2015)
PD1	0.26 ± 0.16	-	0.11 ± 0.15	Padhi <i>et al.</i> (2015)

Table 12. Heritability estimates of egg production up to 40 weeks of age as reported in literature

Breed/Strain	h^2_s	h^2_D	h^2_{s+D}	Reference
IWH	0.04 ± 0.08	0.07 ± 0.17	0.05 ± 0.10	Chatterjee <i>et al.</i> (2008)
IWI	0.08 ± 0.09	0.14 ± 0.14	0.11 ± 0.08	
IWK	0.14 ± 0.12	0.29 ± 0.18	0.22 ± 0.11	
Control(WLH)	0.43 ± 0.18	0.19 ± 0.15	0.31 ± 0.12	
RIR	-	-	0.70 ± 0.16	Jilani <i>et al.</i> (2007)
IWH	0.173 ± 0.12	-	0.087 ± 0.07	Jayalaxmi (2008)
IWI	0.098 ± 0.084	0.234 ± 0.137	0.164 ± 0.065	
IWK	0.118 ± 0.12	-	0.059 ± 0.07	
Control(WLH)	0.145 ± 0.11	-	0.072 ± 0.06	
Nacked neck	0.14 ± 0.29	-	0.10 ± 0.22	RajKumar <i>et al.</i> (2012d)
Dwarf	0.02 ± 0.17	0.12 ± 0.39	0.06 ± 0.19	Rajkumar <i>et al.</i> (2011a)
PD1	-	0.31 ± 0.33	0.10 ± 0.19	Padhi and Chatterjee (2012)
IWH	0.048 ± 0.096	0.173 ± 0.073	0.100 ± 0.013	Sreenivas (2013)
IWI	0.113 ± 0.067	0.167 ± 0.210	0.117 ± 0.121	
IWK	0.132 ± 0.071	0.216 ± 0.122	0.129 ± 0.096	
Control(WLH)	0.208 ± 0.156	0.225 ± 0.054	0.138 ± 0.077	
PD1	0.02 ± 0.21	0.41 ± 0.39	0.22 ± 0.23	Padhi <i>et al.</i> (2015)
PD1	0.01 ± 0.12	0.06 ± 0.24	0.03 ± 0.14	Padhi <i>et al.</i> (2015a)

heritability based on S+D component varied from 0.03 ± 0.14 in PD1 (Padhi *et al.*, 2015a) to 0.70 ± 0.16 (Jilani *et al.*, 2007).

2.5.6 Correlation estimates for body weights, AFE and production traits

The genetic and phenotypic correlations of BW40 with AFE and production traits in various breeds / genotypes / varieties as reported in the literature are presented in Table (13). The genetic correlation of BW40 with AFE varied widely with some reports indicating negative (Jayalaxmi, 2008) while others indicating positive correlations (Sreenivas, 2013) which ranged from -0.26 ± 0.36 (Chatterjee *et al.*, 2008) to 0.70 ± 0.69 (Sreenivas, 2013). Whereas the reports for genetic correlation of BW40 with egg weights ranged from -0.45 ± 0.35 in IWH (Chatterjee *et al.*, 2008) to 0.804 ± 0.155 in IWK strain (Sreenivas, 2013). Genetic correlation of BW40 with EP40 in IWH varied from -0.84 ± 0.48 (Jayalaxmi, 2008) to 0.83 ± 0.25 (Chatterjee *et al.*, 2008).

The phenotypic correlations of BW40 with AFE are reported to be low in magnitude but mostly positive in direction which ranged from -0.03 (Chatterjee *et al.*, 2008) in IWI to 0.36 ± 0.003 (Jilani *et al.*, 2007) in RIR. Whereas the phenotypic correlations of AFE with egg weights ranged from -0.102 in IWK (Sreenivas, 2013) to 0.17 in dwarf chicken (Rajkumar *et al.*, 2011a).

The reports on genetic and phenotypic correlations of AFE with EW28, EW40 and EP40 are compiled and presented in Table (14). Genetic correlation between AFE and egg weights in the published reports ranged from 0.946 ± 0.167 (Chatterjee *et al.*, 2008) to -0.489 ± 0.46 (Jayalaxmi, 2008) in IWK and WLH control populations respectively.

Table 13. Correlations of body weight at 40 weeks with AFE, egg production and egg weights in various Breeds of chicken as reported in literature

BW 40 WITH	Breed/Strain	r_g	r_p	Reference
ASM	RIR	0.09 ± 0.0036	0.36 ± 0.003	Jilani <i>et al.</i> (2007)
EP40		-0.06 ± 0.036	-0.18 ± 0.005	
AFE	IWH	-0.44 ± 0.39	-0.01	Chatterjee <i>et al.</i> (2008)
	IWI	0.13 ± 0.46	-0.03	
	IWK	0.42 ± 0.34	0.02	
	Control (WLH)	-0.26 ± 0.36	0.04	
EP40	IWH	0.83 ± 0.25	0.11	
	IWI	0.24 ± 0.72	0.08	
	IWK	-0.45 ± 0.44	-0.02	
	Control(WLH)	0.42 ± 0.25	0.10	
EW28	IWH	-0.45 ± 0.35	0.05	
	IWI	0.40 ± 0.39	0.23	
	IWK	0.57 ± 0.23	0.12	
	Control (WLH)	0.46 ± 0.22	0.15	

(Contd...)

Table 13 (Contd...)

EW40	IWH	-0.26 ± 0.35	0.10	Chatterjee <i>et al.</i> (2008)
	IWI	0.11 ± 0.32	0.20	
	IWK	-0.59 ± 0.21	0.20	
	Control(WLH)	0.58 ± 0.18	0.12	
AFE	IWH	0.224 ± 0.274	0.064	Jayalaxmi (2008)
	IWI	0.410 ± 0.248	0.053	
	IWK	-0.283 ± 0.847	0.036	
	Control(WLH)	0.120 ± 0.462	-0.022	
EP40	IWH	-0.84 ± 0.48	-0.103	
	IWI	-0.24 ± 0.28	0.044	
	IWK	-0.58 ± 0.53	-0.059	
	Control(WLH)	0.08 ± 0.53	0.057	
EW28	IWH	0.55 ± 0.21	0.161	
	IWI	0.69 ± 0.172	0.143	
	IWK	-0.10 ± 0.27	0.054	
	Control(WLH)	-0.16 ± 0.59	0.087	

(Contd...)

Table 13 (Contd...)

EW40	IWH	0.47 ± 0.19	0.128	
	IWI	0.32 ± 0.24	0.121	
	IWK	0.45 ± 0.19	0.214	
	Control(WLH)	0.67 ± 0.38	0.092	
ASM	Dwarf	0.10	0.10	Rajkumar <i>et al.</i> (2011a)
EW40		0.88	0.19	
EP40		-0.10	-0.12	
ASM	PD1	0.50 ± 0.29	0.13	Padhi and Chatterjee (2012)
EW40		0.41 ± 0.31	0.14	
EP40		-0.18 ± 0.64	-0.19	
AFE	IWH	0.267 ± 0.443	-0.004	Sreenivas (2013)
	IWI	0.544 ± 0.271	0.072	
	IWK	0.331 ± 0.163	0.002	
	Control(WLH)	0.700 ± 0.693	0.061	
EP40	IWH		0.030	
	IWI	-0.086 ± 0.419	0.030	
	IWK	-0.220 ± 0.480	-0.007	

Table 13 (Contd...)

EW28	IWH	0.285 ± 0.452	0.103	
	IWI	-	0.180	
	IWK	0.804 ± 0.155	0.167	
	Control(WLH)	0.187 ± 0.037	0.072	
EW40	IWH	0.492 ± 0.320	0.002	Sreenivas (2013)
	IWI	0.626 ± 0.204	0.092	
	IWK	0.472 ± 0.666	0.141	
	Control(WLH)	-0.233 ± 0.696	0.085	
ASM	PD1	0.68 ± 0.45	0.04	Padhi <i>et al.</i> (2015)
EP40		-0.32 ± 0.73	-0.22	

Table 14. Correlations of AFE with egg production and egg weights in various breeds of chicken as reported in literature

AFE WITH	Breed/Strain	r_g	r_p	Reference
EP40	RIR	-0.043 ± 0.036	0.17 ± 0.004	Jilani <i>et al.</i> (2007)
EP40	IWH	-0.77 ± 0.29	-0.21	Chatterjee <i>et al.</i> (2008)
	IWI	-0.69 ± 0.29	-0.22	
	IWK	-0.46 ± 0.38	-0.25	
	Control(WLH)	-0.65 ± 0.21	-0.18	
EW28	IWH	0.92 ± 0.06	0.03	
	IWI	0.19 ± 0.28	0.09	
	IWK	0.30 ± 0.27	0.08	
	Control(WLH)	-0.04 ± 0.32	0.10	
EW40	IWH	0.72 ± 0.29	0.08	
	IWI	0.28 ± 0.26	0.04	
	IWK	-0.20 ± 0.27	-0.02	
	Control(WLH)	0.21 ± 0.31	-0.01	

(Contd...)

Table 14 (Contd...)

EP40	IWH	-0.177 ± 0.503	-0.209	Jayalaxmi (2008)
	IWI	-0.910 ± 0.338	-0.361	
	IWK	0.736 ± 0.231	-0.143	
	Control(WLH)	-0.828 ± 0.898	-0.308	
EW28	IWH	0.351 ± 0.299	0.064	
	IWI	0.508 ± 0.183	0.084	
	IWK	0.424 ± 0.157	0.016	
	Control(WLH)	-	-0.049	
EW40	IWH	-0.116 ± 0.266	0.050	
	IWI	0.265 ± 0.235	0.061	
	IWK	0.417 ± 0.010	0.030	
	Control(WLH)	-0.489 ± 0.460	0.030	
EW40	Dwarf chicken	0.59	0.17	Rajkumar <i>et al.</i> (2011a)
EP40		-0.38	-0.49	
EW40	PD1	0.45 ± 0.37	0.09	Padhi and Chatterjee (2012)
EP40		-0.97 ± 0.05	0.02	

(Contd...)

Table 14 (Contd...)

EP40	IWH	-0.645 ± 0.516	-0.215	Sreenivas (2013)
	IWI		-0.285	
	IWK	-0.356 ± 0.346	-0.314	
	Control(WLH)	-0.366 ± 0.102	-0.303	
EW28	IWH	0.211 ± 0.649	0.079	
	IWI	0.392 ± 0.246	0.053	
	IWK	0.946 ± 0.167	-0.102	
	Control(WLH)	-0.181 ± 0.092	0.045	
EW40	IWH	0.248 ± 0.481	0.031	
	IWI	0.307 ± 0.478	0.076	
	IWK	0.763 ± 0.182	0.022	
	Control(WLH)	-0.118 ± 0.059	-0.060	
EP40	PD1	-	-0.34	Padhi <i>et al.</i> (2015)

Table 15. Correlations of egg weight at 28 weeks with egg production up to 40 weeks and egg weight at 40 weeks in various breeds of chicken as reported in literature

EW28 WITH	Breed/Strain	r_g	r_p	Reference
EW40	IWH	0.85 ± 0.08	0.37	Chatterjee <i>et al.</i> (2008)
	IWI	0.71 ± 0.12	0.40	
	IWK	0.67 ± 0.13	0.37	
	Control(WLH)	0.72 ± 0.11	0.35	
EP40	IWH	-0.95 ± 0.06	-0.01	
	IWI	0.33 ± 0.42	-0.05	
	IWK	-0.90 ± 0.08	-0.09	
	Control(WLH)	-0.03 ± 0.25	-0.04	
EW40	IWH	0.78 ± 0.14	0.475	Jayalaxmi (2008)
	IWI	0.84 ± 0.10	0.435	
	IWK	0.62 ± 0.20	0.421	
	Control(WLH)	-0.67 ± 0.48	0.350	

(Contd...)

Table 15 (Contd...)

EP40	IWH	-0.12 ± 0.42	-0.106	Sreenivas (2013)
	IWI	-0.64 ± 0.23	-0.145	
	IWK	-	-0.030	
	Control(WLH)	0.20 ± 0.83	-0.106	
EP40	IWH	-0.651 ± 0.294	-0.067	
	IWI	-	-0.073	
	IWK	-0.891 ± 0.170	-0.143	
	Control(WLH)	-0.087 ± 0.507	-0.114	
EW40	IWH	0.759 ± 0.77	0.101	
	IWI	0.836 ± 0.313	0.108	
	IWK	0.412 ± 0.162	0.225	
	Control(WLH)	0.385 ± 0.107	0.157	

Table 16. Correlations of egg weight at 40 weeks with egg production up to 40 weeks in various breeds as reported in literature

EW40 WITH	Breed/Strain	r_g	r_p	Reference
EP40	IWH	0.84 ± 0.16	-0.01	Chatterjee <i>et al.</i> (2008)
	IWI	0.30 ± 0.41	0.01	
	IWK	< -1	-0.10	
	Control(WLH)	-0.16 ± 0.25	-0.01	
EP40	IWH	-0.63 ± 0.42	-0.088	Jayalaxmi (2008)
	IWI	-0.35 ± 0.27	-0.093	
	IWK	0.35 ± 0.50	-0.038	
	Control(WLH)	0.62 ± 0.61	-0.073	
EP40	Dwarf	-0.61	-0.19	Rajkumar <i>et al.</i> (2011a)
EP40	PD1	-0.64 ± 0.46	0.02	Padhi and Chatterjee (2012)
EP40	IWH	-0.137 ± 0.493	0.030	Sreenivas (2013)
	IWI	-0.375 ± 0.499	-0.044	
	IWK	-0.806 ± 0.215	-0.125	
	Control(WLH)	-0.550 ± 0.444	-0.064	
EP40	PD1	-0.49	-	Padhi <i>et al.</i> (2015a)

Perusal of literature indicated mostly negative r_g and r_p between AFE and EP40. The genetic correlation ranged from -0.910 ± 0.338 (Jayalaxmi, 2008) in IWI to 0.736 ± 0.231 in IWK (Jayalaxmi, 2008), whereas the phenotypic correlation ranged from -0.361 in IWI (Jayalaxmi, 2008) to 0.02 (Padhi and Chatterjee 2012) in PD1.

The genetic and phenotypic correlations of egg weight at 28 weeks with egg production up to 40 weeks are presented in Table (15). The reported values of r_g between EW28 with EP40 ranged from -0.95 ± 0.06 in IWH to 0.33 ± 0.42 in IWI (Chatterjee *et al.*, 2008) whereas the r_p were negative in direction and ranged from -0.143 (Sreenivas, 2013) to -0.01 (Chatterjee *et al.*, 2008) in IWK and IWH respectively.

The genetic and phenotypic correlations of egg weight at 40 weeks with egg production up to 40 weeks are presented in Table (16). The reported values of genetic and phenotypic correlations of EW40 with EP40 were mostly positive except very few. The genetic correlation of EW40 with EP40 in the reports ranged from -0.806 ± 0.215 in IWK (Sreenivas, 2013) to 0.84 ± 0.16 IWH (Chatterjee *et al.*, 2008). Whereas the phenotypic correlations ranged from -0.125 in IWK to 0.03 in IWH strain (Sreenivas, 2013).

CHAPTER III

MATERIALS AND METHODS

3.1 EXPERIMENTAL POPULATION

RAJASRI, a synthetic poultry variety involving 56.25% Rhode Island Red, 6.25% White Leghorn, 12.50% Dahlem Red and 25% native chicken inheritance was developed at Poultry Research Station, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad to suit backyard production under free range condition. The present study was undertaken to assess the performance of these birds.

A total of 2931 chicks were produced from 77 sires and 308 dams in 12 hatches. Chicks were reared in deep litter system of management up to 16 weeks of age and thereafter were shifted to individual cages to obtain production data.

3.2 TRAITS STUDIED

The following parameters were recorded on each individual bird:

1. Body weight (g) at different ages - 28, 32, 36 and 40 weeks.
2. Age at first egg (AFE) – The age of the bird in days when the first egg was laid.
3. Egg production – Measured as total number of eggs laid up to 40 weeks of age by each bird.
4. Egg weight – The average weight of eggs laid in five consecutive days at 28 and 40 weeks of age.
5. Fertility – Calculated as ratio of number of fertile eggs based on candling results on 18th day to total number of eggs loaded, expressed in percentage.

6. Hatchability

1. Total Eggs Set (TES) – Percentage of chicks hatched out of total number of eggs set for incubation.
2. Fertile Eggs Set (FES) – Percentage of chicks hatched out of fertile eggs set based on results of candling.

In the present study fertile eggs produced from the parent stock (stock under study) are used for the production of Rajasri day old chicks which are supplied to the farming community at PRS (Poultry Research Station) routinely. For studying fertility and hatchability, data pertaining to 10 hatches taken between January to March, 2016 were utilized. During this period the age of parent stock ranged from 35 to 45 weeks of age.

7. Egg quality traits – A total of 36 eggs (3 from each hatch of Rajasri birds) were randomly collected at 40 weeks of age and used for studying various external and internal egg quality parameters.

Traits measured are haugh unit, albumen index, yolk index, yolk colour, shell colour, shell thickness (mm), shell weight (g).

The egg weights were measured to the precision of 0.01 g. Then, the eggs were broken for measuring the internal egg quality traits like albumen height, haugh unit etc. Length and width of thick albumen were measured at the longest point by vernier calipers with a precision of 0.05mm. The width of the yolk was measured twice at right angles to each other and arrived at the average of these two readings. The height of yolk was measured at its highest point by the

spirometer. The shells of the broken eggs were dried at room temperature. Thereafter the weight was measured closest to 0.01 g accuracy. The shell thickness was measured to 0.01 mm utilizing a screw gauge at three spots on the shell - one at the broader end, second at the narrow end and third at center of these both and average of these was considered as the mean shell thickness. The albumen and yolk indices were resolved as the ratio of height to width of albumen and yolk according to Heimen and Carver (1936) and Funk (1948) respectively.

3.3 STATISTICAL ANALYSIS

The pedigreed data were analyzed using least squares technique (Harvey, 1990; Fixed effect model) to find out effect of hatch on the traits studied. Significant differences between means were tested by using Duncan's Multiple Range Test (Duncan, 1955). Hatch corrected data was used for estimation of genetic parameters by full-sib analysis method.

The statistical model for least squares analysis was

$$Y_{ijk} = \mu + h_i + s_j + e_{ijk}$$

where,

Y_{ijk} = measurement of a trait on k^{th} bird belonging to i^{th} hatch and j^{th} sex

μ = overall mean

h_i = effect of i^{th} hatch

s_j = effect of j^{th} sex

e_{ijk} = random error, normally and independently distributed with a mean zero and variance σ_e^2 .

3.3.1 Estimation of heritability

The hatch corrected data were utilized for the estimation of genetic parameters by full sib correlation method using Harvey's Mixed Model least-squares and maximum likelihood (LSMLMW) computer program (1990). The statistical model for the estimation of heritability of traits studied was as follows.

$$Y_{ijk} = \mu + s_i + d_{ij} + e_{ijk}$$

Where,

Y_{ijk} = measurement of a trait on k^{th} progeny belonging to j^{th} dam mated to i^{th} sire.

μ = Overall mean

s_i = effect of i^{th} sire

d_{ij} = the effect of j^{th} dam mated to the i^{th} sire

e_{ijk} = uncontrolled environmental and genetic deviations attributable to the individuals.

3.3.2 Estimation of co-efficient of correlation

The genetic, phenotypic and environmental correlations between various traits were estimated using Harvey's least-squares and maximum likelihood computer program (1990).



Fig. 1. Rajasri Cock



Fig. 2. Rajasri Hen

CHAPTER IV

RESULTS

4.1 BODY WEIGHTS

4.1.1 Body weight at 28 weeks of age (BW28)

Least squares analysis was carried out to find hatch and sex effects on 28 week body weight and the results are presented in Table 18.

The overall mean for BW28 was 1628.38 ± 3.99 g which ranged from 1586.16 ± 10.62 g to 1669.27 ± 14.27 g in various hatches (Table 17). At 28 weeks of age males weighed 1864.21 ± 6.18 g while females weighed 1392.54 ± 4.67 g. Hatch and sex of the birds had significantly ($P \leq 0.01$) influenced the body weight at 28 weeks of age.

4.1.2 Body weight at 32 weeks of age (BW32)

The overall mean body weight at 32 weeks of age was 1693.36 ± 4.00 g which ranged from 1658.98 ± 21.65 g to 1745.93 ± 14.32 g among 12 hatches (Table 17). The body weight of males and females at 32 weeks of age was 1929.63 ± 6.21 and 1457.07 ± 4.68 respectively and the differences were highly significant.

Table 17. Least squares means (in g) of body weights at different age groups in Rajasri birds

Effect	BW28	BW32	BW36	BW40
Overall	1628.38 ± 3.99	1693.36 ± 4.00	1746.37 ± 4.18	1809.11 ± 4.51
Hatch				
1	1610.61 ± 10.11 ^b	1693.68 ± 10.15 ^{bc}	1755.57 ± 10.61 ^{bcd}	1804.53 ± 11.44 ^{bcd}
2	1627.79 ± 10.55 ^{ab}	1710.70 ± 10.59 ^{ab}	1780.81 ± 11.07 ^b	1819.22 ± 11.94 ^{abc}
3	1586.16 ± 10.62 ^a	1680.64 ± 10.66 ^a	1707.00 ± 11.14 ^a	1775.77 ± 12.02 ^a
4	1613.23 ± 11.21 ^b	1668.58 ± 11.25 ^{ab}	1734.42 ± 11.76 ^b	1775.24 ± 12.69 ^{ab}
5	1650.54 ± 11.30 ^c	1703.31 ± 11.34 ^{cde}	1729.76 ± 11.86 ^{bc}	1784.22 ± 12.79 ^{bc}
6	1636.91 ± 10.84 ^c	1685.65 ± 10.88 ^{def}	1746.09 ± 11.37 ^{de}	1785.89 ± 12.27 ^{cde}
7	1669.27 ± 14.27 ^c	1745.93 ± 14.32 ^{ef}	1810.80 ± 14.97 ^{ef}	1851.09 ± 16.14 ^{ef}
8	1645.47 ± 2.99 ^{cd}	1743.25 ± 13.00 ^g	1791 ± 13.97 ^f	1840.91 ± 14.14 ^{fg}
9	1640 ± 15.22 ^c	1702.96 ± 15.28 ^{def}	1750.57 ± 15.97 ^{cde}	1782.18 ± 17.22 ^{bcd}
10	1627.51 ± 21.57 ^c	1658.98 ± 21.65 ^{cd}	1702.93 ± 22.63 ^{bcd}	1804.90 ± 24.41 ^{def}
11	1602.97 ± 10.96 ^{cd}	1663.98 ± 14 ^{fg}	1719.07 ± 11.50 ^{ef}	1833.53 ± 12.40 ^{gh}
12	1630 ± 15.88 ^d	1662.60 ± 15.94 ^{fg}	1728.47 ± 16.66 ^{ef}	1851.81 ± 17.97 ^g
Sex				
Male	1864.21 ± 6.18	1929.63 ± 6.21	1961.14 ± 6.48	1998.65 ± 6.99
Female	1392.54 ± 4.67	1457.07 ± 4.68	1531.59 ± 4.89	1619.55 ± 5.28

Means with different superscripts in a column differ significantly ($P \leq 0.01$)

Table 18. ANOVA of least squares analysis of body weights at different ages in Rajasri birds

Source (d.f.)	Trait	Mean Square	F value
Hatch (11)	BW28	131,143.37	3.71**
	BW32	169,947.47	4.78**
	BW36	236,510.56	6.08**
	BW40	189,149.65	4.18**
Sex (1)	BW28	139,135,115.64	3,939.83**
	BW32	139,657,871.21	3,925.47**
	BW36	115,397,210.95	2,968.95**
	BW40	89,883,805.08	1,987.54**
Error (2918)	BW28	35,315.00	
	BW32	35,577.35	
	BW36	38,868.00	
	BW40	45,223.70	

**Significant ($P \leq 0.01$)

The results obtained from the least squares analysis for body weight at 32 weeks of age (Table 18) indicated significant ($P \leq 0.01$) differences between the hatches and sex.

4.1.3 Body weight at 36 weeks of age (BW36)

The least squares means obtained in the present study for body weight at 36 weeks of age are presented in the Table17. The overall mean for BW36 was $1746.37 \pm 4.18\text{g}$ which ranged from $1702.93 \pm 22.63\text{g}$ to $1810.80 \pm 14.97\text{g}$ among various hatches which did not show any specific trend. Whereas the body weight at 36 weeks of age was $1961.14 \pm 6.48\text{g}$ in males and $1531.59 \pm 4.89\text{g}$ in females showing significant sexual dimorphism.

The result of least squares analysis for body weight at 36 weeks is presented in Table 18. Hatch and sex had significant ($P \leq 0.01$) effect on BW36.

4.1.4 Body weight at 40 weeks of age (BW40)

The results of least squares means and least squares analysis of BW40 are presented in the Table 17 and 18 respectively.

The overall mean body weight at 40 weeks of age was $1809.11 \pm 4.51\text{g}$ and it ranged from $1775.24 \pm 12.69\text{g}$ to $1851.81 \pm 17.97\text{g}$ among different hatches. At 40 weeks, males were significantly heavier ($1998.65 \pm 6.99\text{g}$) than females ($1619.55 \pm 5.28\text{g}$).

4.2 PRODUCTION PERFORMANCE

4.2.1 Age at first egg (AFE)

The results of least squares means for age at first egg are presented in the Table 19 and least squares analysis are presented in Table 20. The overall mean for AFE in the study was 164.74 ± 0.24 days which varied from 156.79 ± 1.13 to 169.24 ± 1.40 days in different hatches. The age at first egg in the present study was significantly ($P \leq 0.01$) influenced by the hatch.

4.2.2 Egg production up to 40 weeks of age (EP40)

The results of least squares means and least squares analysis for EP40 are presented in the Tables 19 and 20 respectively. Hatch of the birds had significantly ($P \leq 0.01$) influenced the egg production up to 40 weeks of age. The average egg production up to 40 weeks of age was 61 ± 0.43 eggs which ranged from 55.22 ± 2.47 to 63.87 ± 1.04 eggs in different hatches.

Table 19. Least squares means of AFE and production traits in Rajasri birds

Effect	AFE (days)	EP40	EW28 (g)	EW40 (g)
Overall	164.74 ± 0.24	61.00 ± 0.43	42.43 ± 0.08	43.79 ± 0.09
Hatch				
1	169.19 ± 0.59 ^f	63.83 ± 1.05 ^d	43.24 ± 0.21 ^{cd}	44.55 ± 0.24 ^d
2	169.03 ± 0.57 ^f	63.27 ± 1.01 ^{cd}	43.58 ± 0.20 ^d	45.71 ± 0.23 ^e
3	166.66 ± 0.58 ^e	63.87 ± 1.04 ^d	43.80 ± 0.21 ^d	46.36 ± 0.24 ^e
4	163.96 ± 0.65 ^{cd}	63.01 ± 1.16 ^{cd}	42.38 ± 0.23 ^{abc}	45.85 ± 0.26 ^e
5	166.00 ± 0.68 ^{de}	63.57 ± 1.21 ^d	42.68 ± 0.24 ^{bc}	47.43 ± 0.28 ^f
6	164.47 ± 0.69 ^{cde}	61.71 ± 1.23 ^{bcd}	41.92 ± 0.25 ^{ab}	41.94 ± 0.28 ^b
7	161.07 ± 0.86 ^b	58.50 ± 1.53 ^{abc}	42.47 ± 0.31 ^{abc}	41.74 ± 0.35 ^b
8	166.40 ± 0.84 ^{de}	59.04 ± 1.50 ^{abcd}	41.69 ± 0.30 ^a	40.48 ± 0.34 ^a
9	162.68 ± 0.96 ^{bc}	58.13 ± 1.70 ^{ab}	41.84 ± 0.34 ^{ab}	41.81 ± 0.39 ^b
10	169.24 ± 1.40 ^f	55.22 ± 2.47 ^a	41.56 ± 0.49 ^a	43.00 ± 0.56 ^c
11	161.40 ± 0.78 ^b	60.53 ± 1.38 ^{bcd}	42.33 ± 0.28 ^{abc}	43.34 ± 0.31 ^c
12	156.79 ± 1.13 ^a	61.26 ± 2.00 ^{bcd}	41.70 ± 0.40 ^a	43.38 ± 0.45 ^c

Means with different superscripts in a column differ significantly ($P \leq 0.01$)

Table 20. ANOVA of least squares analysis of production traits in Rajasri chicken

Source (d.f)	Trait	Mean Square	F value
Hatch (11)	AFE	1754.99	19.83**
	EP40	838.11	3.04**
	EW28	97.54	8.87**
	EW40	761.99	53.77**
Error (1933)	AFE	88.46	
	EP40	275.16	
	EW28	10.98	
	EW40	14.17	

**Significant ($P \leq 0.01$)

4.2.3 Egg weights

The results of least squares means and hatch and sex wise least squares analysis for egg weights at 28 weeks and at 40 weeks of age are presented in the Tables 19 and 20 respectively.

The egg weight at 28 weeks of age in the present study in different hatches ranged from 41.56 ± 0.49 to 43.80 ± 0.21 g with overall mean of 42.43 ± 0.08 g. Whereas Egg weight at 40 weeks in present study ranged from 40.48 ± 0.34 g to 47.43 ± 0.28 g with an overall mean of 43.79 ± 0.09 g.

4.3 Fertility and Hatchability

The fertility and hatchability estimates obtained in the present study are shown in Table 21. Mean per cent fertility in the present study was 82.65 which ranged from 77.78 to 87.33 across the hatches. The mean hatchability on TES was found to be 72.96 per cent which ranged from 69.31 to 77.67 per cent, while the overall mean hatchability based on FES was found to be 88.02 per cent, which varied from 86.66 to 91.82 per cent.

4.4 Egg quality parameters

The results of egg quality traits in Rajasri birds are presented in Table 22. In the present study, average egg shell weight, shell thickness, haugh unit score, albumen index,

Table 21. Per cent fertility and hatchability in Rajasri chicken

Effect	Eggs set	Eggs fertile	Fertility %	Hatched eggs	Hatchability (%)	
					TES	FES
Hatch-1	2147	1843	85.84	1600	74.52	86.81
Hatch-2	2477	2077	83.85	1800	72.67	86.66
Hatch-3	3601	2801	77.78	2507	69.62	86.81
Hatch-4	3613	3092	85.58	2725	75.42	88.13
Hatch-5	3314	2894	87.33	2574	77.67	88.94
Hatch-6	3599	3059	85.00	2680	74.47	87.61
Hatch-7	4617	3667	79.42	3200	69.31	87.26
Hatch-8	3344	2644	79.07	2350	70.28	88.88
Hatch-9	3991	3266	81.83	2850	71.41	87.26
Hatch-10	2345	1895	80.81	1740	74.20	91.82
Overall	27238	27238	82.65	24026	72.96	88.02

TES – Total egg set; FES – Fertile egg set.

Table 22. Means \pm SE of Egg quality parameter in Rajasri chicken

S.No.	TRAITS	MEAN \pm S.E.
1	Shell weight (g)	4.45 \pm 0.07
2	Shell thickness (mm)	0.33 \pm 0.01
3	Haugh unit	86.31 \pm 1.12
4	Albumin index	0.09 \pm 0.01
5	Yolk index	0.44 \pm 0.01
6	Yolk colour	6.78 \pm 0.16
7	Shell colour	(in per cent)
	(a) Brown	61.11
	(b) Light brown	30.56
	(c) White	8.33

yolk index and yolk colour were 4.45 ± 0.07 g; 0.33 ± 0.01 mm; 86.31 ± 1.12 ; 0.09 ± 0.01 ; 0.44 ± 0.01 and 6.78 ± 0.16 respectively. Wide variation in shell colour was observed in Rajasri eggs with a proportion of 61.11 % brown, 30.56 % light brown and 8.33 % white shell eggs.

4.5 ESTIMATION OF GENETIC PARAMETER

4.5.1 Heritability estimates for body weights

Heritability estimates of body weights along with their standard errors are presented in Table 23.

Heritability estimates based on sire, dam and S+D components were 0.03 ± 0.08 , 0.32 ± 0.14 and 0.17 ± 0.08 for BW28; 0.13 ± 0.09 , 0.30 ± 0.14 and 0.21 ± 0.08 for BW32; 0.07 ± 0.09 , 0.47 ± 0.15 and 0.27 ± 0.09 for BW36 and 0.10 ± 0.09 , 0.37 ± 0.14 and 0.24 ± 0.09 for BW40, respectively.

4.5.2 Heritability estimates for AFE and egg production traits

Heritability estimates of production traits along with their standard errors in Rajasri birds are presented in Table 24. Heritability estimates for AFE based on sire component and S+D component were not estimable; but AFE based on dam component was found to be low (0.01 ± 0.06).

Table 23. Heritability estimates for body weights in Rajasri chicken

Trait	$h^2_S \pm SE$	$h^2_D \pm SE$	$h^2_{S+D} \pm SE$
BW28	0.03 ± 0.08	0.32 ± 0.14	0.17 ± 0.08
BW32	0.13 ± 0.09	0.30 ± 0.14	0.21 ± 0.08
BW36	0.07 ± 0.09	0.47 ± 0.15	0.27 ± 0.09
BW40	0.10 ± 0.09	0.37 ± 0.14	0.24 ± 0.09

Table 24. Heritability estimates of egg production traits in Rajasri chicken

Trait	$h^2_S \pm SE$	$h^2_D \pm SE$	$h^2_{S+D} \pm SE$
AFE	£	0.01 ± 0.06	£
EP40	0.06 ± 0.04	0.05 ± 0.06	0.06 ± 0.04
EW28	0.19 ± 0.06	0.11 ± 0.07	0.15 ± 0.08
EW40	0.10 ± 0.04	0.02 ± 0.06	0.06 ± 0.07

The h^2_S , h^2_D and h^2_{S+D} estimates for egg production up to 40 weeks were 0.06 ± 0.04 , 0.05 ± 0.06 and 0.06 ± 0.04 respectively.

The heritability estimates based on sire, dam and S+D components were 0.19 ± 0.06 ; 0.11 ± 0.07 and 0.15 ± 0.08 respectively for EW28 and were 0.10 ± 0.04 ; 0.02 ± 0.06 and 0.06 ± 0.07 respectively for EW40.

4.5.3 Genetic and phenotypic correlation among body weights and egg production traits

Genetic correlations among body weights and egg production traits are presented in Table 25. Genetic correlation estimates among body weights were positive and high in magnitude ranging from 0.62 ± 0.16 to 0.98 ± 0.08 . Perusal of the results indicated that the genetic correlations of 36 week body weight with 40 week body weights were highest in magnitude.

Genetic correlations between AFE with all other traits were not estimable. While the genetic correlations of EP40 with body weights were negative in direction and low in magnitude.

The phenotypic correlations among body weights and production traits are presented in the Table 25. The phenotypic correlations among body weights were positive and high in magnitude ranging from 0.50 ± 0.02 to 0.83 ± 0.01 . The phenotypic

Table 25. Genetic correlations from S+D component (above diagonal) and phenotypic correlations (below diagonal) between various production traits in Rajasri chicken

Trait	BW28	BW32	BW36	BW40	AFE	EP40	EW28	EW40
BW28	-	£	0.80 ± 0.11	0.62 ± 0.16	£	-0.04 ± 0.29	0.23 ± 0.19	-0.10 ± 0.30
BW32	0.83 ± 0.01	-	0.97 ± 0.08	0.84 ± 0.12	£	-0.09 ± 0.30	0.46 ± 0.19	0.06 ± 0.31
BW36	0.64 ± 0.01	0.73 ± 0.01	-	0.98 ± 0.08	£	-0.09 ± 0.30	0.39 ± 0.12	0.03 ± 0.30
BW40	0.50 ± 0.02	0.60 ± 0.01	0.71 ± 0.01	-	£	0.09 ± 0.29	0.12 ± 0.20	0.13 ± 0.30
AFE	0.02 ± 0.02	0.03 ± 0.02	0.03 ± 0.02	0.03 ± 0.02	-	£	£	£
EP40	0.04 ± 0.02	0.02 ± 0.02	0.02 ± 0.02	-0.01 ± 0.02	-0.07 ± 0.02	-	-0.33 ± 0.27	-0.47 ± 0.40
EW28	0.21 ± 0.02	0.21 ± 0.02	0.16 ± 0.02	0.18 ± 0.02	0.03 ± 0.02	0.04 ± 0.02	-	0.98 ± 0.26
EW40	0.05 ± 0.02	0.05 ± 0.02	0.07 ± 0.02	0.12 ± 0.02	-0.01 ± 0.02	-0.06 ± 0.02	0.28 ± 0.02	-

£ - Not estimable

correlations observed between AFE and body weights in the present study were positive but low in magnitude. The r_p of AFE with EP40 and EW40 were negative and low in magnitude. While the phenotypic correlation of EP40 with body weights were positive and low in magnitude. The phenotypic correlation of EP40 with EW28 was positive while it was negative with EW40.

CHAPTER V

DISCUSSION

5.1 PERFORMANCE TRAITS

Synthetic backyard poultry variety “RAJASRI” was evolved keeping in view the specific requirements *viz.*, medium size, long shanks, better flight with capacity to lay about 125-150 eggs per annum under free range conditions. Present study was taken up to study productive performance and genetic architecture of this population.

5.1 BODY WEIGHTS

5.1.1 Body weight at 28 weeks of age (BW28)

Body weight plays an important role in backyard poultry rearing as it does not only influence egg production but also determines flight of the bird. Hence, optimization of body weight is very essential in backyard poultry varieties.

In the present study, overall mean body weight at 28 weeks of age was 1628.38 ± 3.99 g, which was significantly influenced by sex and hatch. Males were heavier (1864.21 ± 6.18 g) than females (1392.54 ± 4.67 g). The BW28 of Rajasri birds was lower than Vanaraja (Kalita *et al.*, 2012) and Lohmann brown (Usturoi *et al.*, 2006) genotype which is expected as this bird has 25% local bird inheritance and the body weight was aimed to be low for better flight under free range conditions.

5.1.2 Body weight at 32 weeks of age (BW32)

The BW32 of Rajasri males and females in the present study were 1929.63 ± 6.21 and 1457.07 ± 4.68 g respectively with an overall mean of 1693.36 ± 4.00 g which was lower than other backyard poultry varieties (Kalita *et al.*, 2012; Padhi and Chatterjee, 2012).

5.1.3 Body weight at 36 weeks of age (BW36)

The mean body weights at 36 weeks of age (BW36) was 1961.14 ± 6.48 and 1531.59 ± 4.89 g in males and females, while the overall mean BW36 was 1746.37 ± 4.18 g. The difference between sexes was significant ($P \leq 0.01$). Usturoi *et al.* (2006) reported higher body weight (1837.79 ± 29.61 g) in Lohmann brown chicken .

5.1.4 Body weight at 40 weeks of age (BW40)

The mean BW40 in the present study was 1809.11 ± 4.51 g. Males were found to be significantly heavier (1998.65 ± 6.99 g) than females (1619.55 ± 5.28 g). Sexual dimorphism in favour of males was also reported by many authors (Malik *et al.*, 2009; Malik and Singh, 2010; Rao *et al.*, 2012; Sankhyan and Thakur 2016).

Jilani *et al.*, (2005) and (2007); Anees *et al.* (2010) and Prasad *et al.* (2012) also reported similar body weights in RIR, WLH and Delham Red breeds. However, Islam *et al.* (2014); Padhi *et al.* (2014); Padhi *et al.* (2015) and Sankhyan and Thakur (2016) reported higher values for backyard poultry varieties having broiler

inheritance. While, lower body weights were reported by Jha *et al.* (2013a) in native chickens (Hazra, Aseel and Kadaknath).

In general, body weight of Rajasri birds was higher than native chicken breeds and lower than synthetic backyard varieties *viz.*, Vanaraja, Giriraja etc., evolved by using exotic broiler breeds as one of the parent line. It is expected as Rajasri birds were evolved using native chicken and exotic layer breeds to optimize body weight so that birds are agile and retain flight which is essential in free range conditions.

5.2 PRODUCTION PERFORMANCE

5.2.1 Age at first egg (AFE)

The age at first egg was found to be significantly ($P \leq 0.01$) different among the hatches. The AFE in the present study was 164.74 days which was less than the AFE reported for native breeds *viz.*, Horro, Aseel, Hazra, Kadaknath, Brown Nicobari, Miri type, Naked Neck, Dwarf and Black Nicobari (Haunshi *et al.*, 2009; Dana *et al.*, 2011; Rajkumar *et al.*, 2011; Rajkumar *et al.*, 2011a; Jha *et al.*, 2013a; Kundu *et al.*, 2015). Whereas, the mean AFE reported for exotic layer breeds *viz.*, Rhode Island Red and White Leghorn were lower than the mean AFE of present study (Jilani *et al.*, 2007; Yi *et al.*, 2014). It is expected that AFE of Rajasri birds will be intermediate as it is evolved by combining early maturing exotic layer breeds and late maturing native chicken.

5.2.2 Part year egg production up to 40 weeks of age (EP40)

Egg production is the primary trait in laying birds. Part year egg production up to 40 weeks of age is considered in the present study. Significant difference in egg production up to 40 weeks of age was observed among the twelve hatches.

In the present study, mean EP40 was 61.00 ± 0.43 eggs. EP40 recorded in the present study is comparable with the values reported for Rajasri birds (Rao *et al.*, 2012) and Dahlem Red X Desi (Jha *et al.*, 2013b), but was lower than certain synthetic varieties *viz.*, Gramapriya (67.42 ± 3.56) reported by Jha *et al.* (2013) and PD1 X IWI X PD3 (91.71 ± 1.37) cross reported by Padhi *et al.* (2016).

The mean EP40 of Rajasri birds in the present study was higher than that of native breeds (Niranjan *et al.*, 2008a; Haunshi *et al.*, 2009; Jha *et al.*, 2013a), but was less than exotic layer breeds *viz.*, White Leghorn, Rhode Island Red, White Leghorn strains and Dahlem Red (Kataria and Johari, 2001; Jilani *et al.*, 2005; Jilani *et al.*, 2007; Mallick and Ghosh, 2008; Jayalaxmi *et al.*, 2010; Sreenivas., 2013; Kalita *et al.*, 2015). The results are on expected lines as Rajasri variety is evolved by systematic breeding using native non-descript birds and exotic layer breeds *viz.*, Rhode Island Red, Dahlem Red and White Leghorn.

5.2.3 EGG WEIGHTS

5.2.3.1 Egg weight at 28 weeks of age (EW28)

The overall mean for EW28 in the present study was 42.43g and it was significantly influenced by hatch. The EW28 recorded in Rajasri flock in the present study was comparable with the values reported by Haunshi *et al.* (2011) in Aseel and by Rajkumar *et al.* (2011) in Vanaraja. However, higher values were reported in native breeds, their crosses with exotic breeds and synthetic varieties *viz.*, Vanaraja, Gramapriya, Naked neck, Dwarf, DW X PB2, PD1 and PD1 X IWI X PD3 which are heavier genotypes compared to Rajasri (Rajkumar *et al.*, 2011; Rajkumar *et al.*, 2011a; Rajkumar *et al.*, 2012b; Padhi *et al.*, 2015a; Padhi *et al.*, 2016).

5.2.3.2 Egg weight at 40 weeks of age (EW40)

The overall mean for EW40 was 43.79g and it was significantly influenced by hatch effect. The mean for EW40 in the present study was in close agreement with the values reported in literature for Kalasthi (Vij *et al.*, 2006); Kadaknath (Niranjan *et al.* (2008a); Aseel × WLH (Rao *et al.*, 2010) and Aseel (Jha *et al.*, 2013a).

The EW40 in the Rajasri birds under study was higher than the values reported in native breeds, their crosses with exotic breeds and synthetic varieties *viz.*, Ghagus, Miri type, Kadaknath, Aseel and CARI – Debendra (Singh 2005; Vij *et al.*, 2006; Haunshi *et al.*, 2011). However, higher egg weights than the one observed in the present study were reported in Vanaraja and Gramapriya (Hajra *et al.*, 2014); Rajasri

(Naga Raja Kumari *et al.*, 2014); PD1 X IWI X PD3 (Padhi *et al.*, 2016) and C1 cross (Niranjan *et al.*, 2008c) which can be due to higher body weight of these genotypes.

5.3 Fertility and hatchability

The fertility percentage in Rajasri birds varied from 77.78 to 87.33 with an overall mean of 82.65 (Table 21). These results are similar to the reports of Niranjan *et al.* (2008); Rajkumar *et al.* (2011a) in PD1 line and Dwarf chicken, but are slightly higher than those observed by Singh *et al.* (2011a); Das *et al.* (2014). However, slightly lower values were also reported among other improved varieties *viz.*, CARI Shyama, CARI Nirbheek, and coloured broiler sire line (Malik *et al.*, 2009b, Malik *et al.*, 2010 and Malik *et al.*, 2011b). Comparatively higher values of fertility and hatchability were observed in the crosses involving coloured broiler (Mahtre *et al.*, 2008 and Ravi *et al.*, 2008).

The mean hatchability percentage on TES recorded in the present investigation ranged from 69.31 to 77.67 per cent with an overall percentage of 72.96. Similarly, the mean hatchability percentage on FES ranged from 86.66 to 91.82 per cent with an overall hatchability percentage of 88.02 (Table 21). Lower hatchability (TES) estimates were reported by Kumar *et al.* (2008b); Patel *et al.* (2013) in Tellicherry and Gramapriya chicken respectively. Whereas, higher hatchability estimates were reported by Rajkumar *et al.* (2012a) in *Gramapriya* male line birds. With respect to hatchability on FES, slightly lower values were reported by Rajkumar *et al.* (2012a) in *Gramapriya* male line and Das *et al.* (2014) in CARI-Sonali, CARI-Debendra and RIR strains.

5.4 Egg quality traits

All egg quality traits were measured on eggs obtained from birds during 35 to 40 weeks of age. The haugh unit, a measure of albumin quality was found to be 86.31 ± 1.12 which was higher than mean values reported in Aseel, Kadaknath, strains of WLH and Hazra (Haunshi *et al.*, 2011; Sreenivas, 2013; Jha *et al.*, 2013a) while the present estimates were lower than the values reported by Kundu *et al.* (2015) and Rath *et al.* (2015) in Van \times BrN and WLH respectively.

The mean albumen and yolk indices for Rajasri birds in the present study were 0.09 ± 0.01 and 0.44 ± 0.01 respectively and similar values were reported by Rath *et al.* (2015) in WLH. While Rajaravindra *et al.* (2015) and Kalitha *et al.* (2015) reported lower values.

In the present study, the mean shell thickness was found to be 0.33 ± 0.01 mm which is comparable with reported values for PD1, Van \times BN and WLH (Padhi *et al.*, 2015; Kundu *et al.*, 2015; Rath *et al.*, 2015). Rayan *et al.* (2015) and Rajaravindra *et al.* (2015) reported slightly higher shell thickness values in RIR, Bahig, Matrouh and PB2 genotypes.

The mean shell weight recorded in the present study was 4.45 ± 0.07 g which was in close comparison with strains of WLH reported by Sreenivas (2013) but was lower than the reported values in backyard varieties, their crosses and exotic breeds (Kundu *et al.*, 2015; Rayan *et al.*, 2015). These differences are expected as shell weight depends on egg weight which in turn depends on genotype and nutritional

background of their stock.

The mean yolk colour in the present study was found to be 6.78 ± 0.16 which is comparable to the reports of Rajkumar *et al.* (2009) and Padhi *et al.* (2015). Whereas Niranjan *et al.* (2008c) and Rajaravindra *et al.* (2015) reported higher values than the mean values obtained in the present study.

Wide variation was observed in shell colour of Rajasri birds *viz.*, dark brown, light brown and white. This variation may be due to the fact that breeds which lay brown shelled eggs (Rhode Island Red and Native chicken) and white shelled eggs (WLH) were used with varying levels of inheritance while breeding Rajasri birds.

5.5 GENETIC PARAMETERS ESTIMATION

5.5.1 Heritability estimates for Body weights

The h^2 estimates indicate type of gene action which in turn determines the response to selection. These estimates are population and time specific.

The heritability estimates (h^2_S , h^2_D and h^2_{S+D}) in the present study for body weights were low to moderate ranging from 0.03 ± 0.08 to 0.47 ± 0.15 (Table 23). The h^2_D estimates were moderate and higher than h^2_S and h^2_{S+D} estimates among the Rajasri birds. Many reports in the reviewed literature also indicated higher heritability from dam component of variance similar to the present study (Rajkumar *et al.*, 2011; Sreenivas., 2013 and Padhi *et al.*, 2015), while Padhi and Chatterjee (2012) and Rajkumar *et al.* (2011a) reported higher h^2_S values.

5.5.2 Heritability estimates for production traits

In the present study the heritability of age at first egg estimated from dam component was 0.01 ± 0.06 which is low compared to the estimates reported by Rajkumar *et al.* (2011a), Padhi and Chatterjee (2012) and Padhi *et al.* (2015).

The heritability estimates for egg production up to 40 weeks of age (EP40) were 0.06 ± 0.04 , 0.05 ± 0.06 and 0.06 ± 0.04 based on sire, dam and S+D components of variance respectively. Most of the heritability estimates reported for EP40 were found to be low (Chatterjee *et al.*, 2008; Rajkumar *et al.*, 2011a; Padhi *et al.*, 2015a).

The heritability estimates for EW28 and for EW40 weeks were low and these values are in close agreement with the estimates reported by Jayalaxmi *et al.* (2008); Padhi *et al.* (2015) and Chatterjee *et al.* (2008) in various WLH strains.

5.5.3. Genetic and phenotypic correlations among various traits in Rajasri chicken

The correlation estimates enable the breeder to predict the direction and magnitude of change in the dependent trait as a correlated response to direct selection for the principal trait.

The correlation estimates based on the sire component of variance may not be reliable as they are usually based on lesser degrees of freedom. Similarly genetic correlations from dam component are inflated due to covariance of dominant deviations and maternal effects with large standard errors. Therefore, estimates obtained from sire + dam component would be more meaningful than estimates derived from the dam components alone and so are considered in the present discussion.

Genetic correlations from sire + dam component among body weights at different ages in the study were in positive direction with high magnitude and ranged from 0.62 ± 0.16 to 0.98 ± 0.08 (Table 25). Highest and positive genetic correlation was observed between body weight at 36 weeks and body weight at 40 weeks of age. The genetic correlations of EP40 with body weights were negative in direction, which agreed with the reports of Jilani *et al.* (2007); Rajkumar *et al.* (2011a) and Padhi and Chatterjee (2012). It indicated that higher body weight is not desirable in layers and it has to be optimized for balancing egg production and egg weight at desirable levels.

The phenotypic correlation between body weights at different ages in the present study were in positive direction with moderate to high magnitude, which ranged from 0.50 to 0.83. The phenotypic correlations observed between AFE and body weights in the present study were positively correlated but low in magnitude, which corroborate with the findings of Jilani *et al.* (2007) and Rajkumar *et al.* (2011a).

The correlation of AFE with EP40 were negative in direction, which is on expected lines and in close agreement with the earlier reports (Chatterjee *et al.*, 2008; Jayalaxmi, 2008; Rajkumar *et al.*, 2011a; Sreenivas, 2013; Padhi *et al.*, 2015) in White Leghorn and Dwarf chickens.

The phenotypic correlation between EP40 and body weights were positive and low in magnitude, which is in agreement with the findings of Jilani *et al.* (2007); Chatterjee *et al.* (2008); Jayalaxmi (2008); Rajkumar *et al.* (2011a); Padhi and Chatterjee (2012) and Padhi *et al.* (2015) in RIR, WLH, Dwarf and PD1 genotypes . The phenotypic correlations of EP40 with EW28 was positive in direction and same with EW40 was negative in direction which are in agreement with the reports of Chatterjee *et al.* (2008); Jayalaxmi (2008) and Sreenivas (2013).

CHAPTER VI

SUMMARY

Rajasri was evolved as a synthetic backyard poultry variety using 56.25% Rhode Island Red, 6.25% White Leghorn, 12.50% Dalhem Red and 25% of native chicken inheritance at Poultry Research Station, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad. Present study was aimed at evaluating the growth, productive performance and to understand the genetic architecture of Rajasri stock.

A total of 2931 chicks were produced from 77 sires and 308 dams in 12 hatches. Chicks were reared in deep litter system with uniform management up to 16 weeks of age and thereafter were shifted to individual cages to obtain production data.

The overall least squares mean body weights at 28, 32, 36 and 40 weeks of age were 1628.38 ± 3.99 , 1693.36 ± 4.00 , 1746.37 ± 4.18 and 1809.11 ± 4.51 g. Significant ($P \leq 0.01$) hatch and sex effects were observed on body weights at all the ages.

The least squares analysis of AFE, egg weight at 28 weeks of age (EW28), egg weight at 40 weeks of age (EW40) and egg production up to 40 weeks of age (EP40) indicated significant ($P \leq 0.01$) difference among hatches. The overall least squares means of respective traits were 164.74 ± 0.24 days, 42.43 ± 0.08 g, 43.79 ± 0.09 g and 61 ± 0.43 eggs. The mean fertility was 82.65 and hatchability on TES and FES were 72.96 and 88.02 per cent, respectively. The average egg shell weight, shell thickness,

haugh unit score, albumen index, yolk index and yolk colour were 4.45 ± 0.07 g; 0.33 ± 0.01 mm; 86.31 ± 1.12 ; 0.09 ± 0.01 ; 0.44 ± 0.01 and 6.78 ± 0.16 respectively. Wide variation was observed in shell colour consisting of 61.11% brown; 30.56% light brown and 8.33% white shell eggs.

The heritability estimates for body weights at various ages studied were low to moderate in magnitude. Whereas, estimate for AFE was either outside of range or were low in magnitude. The heritability estimates of egg weights at 28 and 40 weeks of age were low. The h^2_s , h^2_D and h^2_{s+D} of egg production up to 40 weeks of age was 0.06 ± 0.04 , 0.05 ± 0.06 and 0.06 ± 0.04 respectively.

The genetic and phenotypic correlations estimates among body weights were positive and high in magnitude ranging from 0.62 ± 0.16 to 0.98 ± 0.08 and 0.50 ± 0.02 to 0.83 ± 0.01 respectively. The genetic correlation of AFE with other traits was found to be outside the range. The phenotypic correlation between AFE and body weights was positive in direction while phenotypic correlation of AFE with EW40 and EP40 was found to be negative. The genetic correlations of EP40 with body weights were negative in direction whereas the phenotypic correlations were positive but low in magnitude.

Thus 'Rajasri', a synthetic variety, evolved by systematic breeding of various exotic layer breeds and local non-descript chicken, is medium in built with production potential similar to other improved backyard poultry varieties.

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