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**Full Research Article**

# Genetic Variability in Immunocompetence and Performance Status of Rhode Island Red Chicken Strains and its Crosses

**Ananta Kumar Das, Sanjeev Kumar*, Abdul Rahim and Anil Kumar Mishra**

Molecular Genetics Laboratory, Avian Genetics & Breeding Division, Central Avian Research Institute, Izatnagar, Bareilly, Uttar Pradesh (243 122), India

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**Correspondence to**

*E-mail*: skgcari@yahoo.co.uk

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**Abstract**

The present investigation envisaged to assess genetic variability in immunocompetence and performance traits in three pure strains of Rhode Island Red (RIR) chicken, viz. $RIR^S$, $RIR^C$ & $RIR^W$, and its two crosses, viz. CARI-Sonali and CARI-Debendra. A total of 3232, 1263, 346, 1278 and 1258 eggs of $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra, were set in three hatches for performance evaluation. Single hatched out 74, 74, 72, 82 and 81 chicks of corresponding genotypes were investigated for immunocompetence status assessed through haemagglutination (HA) test, Lysoplate Assay and Single Radial Immunodiffusion assay. The data on various immunocompetence and performance traits was recorded and analyzed by least squares analysis of variance. The investigation summarized that pure strains demonstrated better immunocompetence than crosses. $RIR^W$ demonstrated highest percent fertility followed by $RIR^C$, $RIR^S$, CARI-Sonali and CARI-Debendra. Highest percent hatchability on total egg set basis was observed in $RIR^C$, whereas CARI-Debendra demonstrated highest percent hatchability on fertile egg set basis. CARI-Debendra demonstrated higher body weights than CARI-Sonali followed by $RIR^S$, $RIR^W$ and $RIR^C$ strains. CARI-Sonali pullets demonstrated ($p<0.05$) least AFE than $RIR^S$ preceded by $RIR^W$, CARI-Debendra and $RIR^C$. Pullets of crosses had ($p<0.05$) higher EW28 and EW40 than pure strains. CARI-Sonali pullets had ($p<0.05$) higher EP40 than $RIR^S$>$RIR^W$=CARI-Debendra>$RIR^C$. There had been significant genotype×sex interaction effect on body weights at 2nd, 8th week and onwards. At 2nd week of age, CARI-Debendra-female showed highest body weight but subsequently CARI-Debendra-males were the heaviest. Effects of hatch, sex and chick weight-regression on growth traits as well as of hatch and housing weight-regression on layer production traits were significant. Crosses demonstrated least percent mortality than pure strains during brooding but reverse in laying stage.

## 1. Introduction

Immunocompetence status of any breed speaks about its general response to diseases. Resistance to diseases is under the control of certain genes involved in the immune response. One of the important non-pathogenic multi-determinant antigens to monitor immune responsiveness in poultry is sheep red blood cells (SRBCs) (Siegel and Gross, 1980). Birds eliciting higher antibody response against SRBCs also produce more antibodies to a variety of antigens (Parmentier et al., 1998). The non-specific components of immune system like lysozyme play important role in the body's defense against infection (Fleming, 1922). Immunoglobulin-G (IgG) is the most abundant immunoglobulin in serum and regarded as an indicator of general immune response (Pinard van der Laan et al., 1998). Since its inception in 1979, Central Avian Research Institute (CARI), Izatnagar (Uttar Pradesh), India has been rearing exotic Rhode Island Red (RIR) chicken and segregated as RIR selected ($RIR^S$) (29th generations till date), control ($RIR^C$) and RIR-White ($RIR^W$) pure strains. The institute had developed CARI-Sonali and CARI-Debendra crosses; by mating males of 'IWH' line of White Leghorn (WLH) with RIR female and males of colored synthetic male line of broilers with RIR female, respectively with the objective to develop a bird that could survive under harsh environmental conditions of rural areas as well as be capable of performing better. Information on genetic variability and relatedness among these chicken

strains and/ or crosses are prerequisite for their exploitation in selective breeding programs. The present investigation was undertaken to assess immunocompetence status and evaluate performances of these RIR strains and crosses.

## 2. Materials and Methods

### *2.1. Experimental units*

A total of 7377 fertile eggs, collected after artificial insemination (AI), at 10 days intervals which included 3232, 1263, 346, 1278 and 1258 eggs of $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra, respectively, were set in three hatches.Single hatched out 74, 74, 72, 82 and 81 chicks at 5-6 weeks of age in corresponding five genotypes and a few Muzaffarnagari breed of sheep (Sheep and Goat Farm, Indian Veterinary Research Institute, Izatnagar) were utilized in immunocompetence study.

### *2.2. Poultry husbandry adopted*

The day-old chicks were wing banded and vaccinated against Ranikhet disease (RD) and Mareck's disease (MD) in the hatchery itself soon after hatching and thereafter transferred on to the litter brooder. After attaining four-weeks of age the chicks were shifted to new brooder house or colony house for 16 weeks after that they were shifted in to individual cages for breeding, laying and pedigree maintenance. The height of hover in the brooder house was adjustable; it could be raised or lowered as per the need of chicks depending on the ambient temperature in the room. Floor space and brooding temperature were provided to the birds as per the standard requirement. As far as light regime was concerned, chicks initially required continuous light for 24 hours in the first three weeks. The lights was decreased @ 2 h $week^{-1}$ till eight-week so as to provide light for about 14 h and thereafter maintained till 16 weeks of age. Water and feed were provided *ad libitum,* two times a day. Birds were fed on CARI-formulated (Division of Avian Nutrition and Feed Technology) chick mash (crude protein-20.65%, metabolic energy-2694.64 Kcal $kg^{-1}$, calcium-1.02%, available phosporous-0.45%, lysine-1.05% and methionine-0.41%) (0-8 weeks), grower mash (crude protein-16.78%, metabolic energy-2536 Kcal $kg^{-1}$, calcium-1.15%, available phosporous-0.40%, lysine-0.76% and methionine-0.37%) (9-20 weeks) and layer mash (crude protein-18.18%, metabolic energy-2676.52 Kcal $kg^{-1}$, calcium-3.61%, available phosporous-0.34%, lysine-0.83% and methionine-0.36%) (21 weeks onwards). Vaccination against RD, MD, infectious bursal disease (IBD), fowl pox and egg dropping syndrome (EDS) was done as per the vaccination schedule followed by Avian Medicine Section, at this institute.

### *2.3. Harvesting of immune sera*

One ml of 1% (v/v) sheep erythrocytes (SRBC) sterile suspension in PBS (pH 7.4) was injected into the jugular vein of each bird at 5-6 weeks of age with tuberculin syringe. Approximately 1 ml blood was collected from jugular vein/ wing vein into 1.5 ml sterile tubes without adding any anticoagulant on $5^{th}$ day post immunization (5 dpi) and allowed to clot keeping the tubes in slanting manner. The hyper immune sera were harvested in 0.5 ml sterile tubes. Sera samples were stored at -20 $^{o}$C till further analysis.

### *2.4. Assessment of immunocompetence traits*

The humoral immune response of chicks was assessed by estimating *in vivo* antibody response to SRBC assessed through haemagglutination (HA) test (Van der Zijpp and Leenstra, 1980). The serum lysozyme concentration was estimated by Lysoplate Assay (Lie et al., 1986) using 1% agarose, in which *Micrococcus lysodieketicus* (Sigma, USA) @ 50 µg $ml^{-1}$ of dibasic buffer was added . Two fold serial dilutions of standard lysozyme (SRL, India) [added @ 2 µg $µl^{-1}$ in dibasic buffer (0.066 M, pH 6.3)] were prepared to get the final concentration of lysozyme as 40 µg $ml^{-1}$, 20 µg $ml^{-1}$, 10 µg $ml^{-1}$, 5.0 µg $ml^{-1}$, 2.5 µg $ml^{-1}$ and 1.25 µg $ml^{-1}$ in order to plot standard curve. A 3% (w/v) agarose gel was used as solidifying base to assay IgG concentrations through Single Radial Immunodiffusion (SRID) assay (Mancini et al., 1965) and the standards of chicken IgG (IgY) (Sigma, USA), viz. 25 mg $ml^{-1}$, 12.5 mg $ml^{-1}$, 6.25 mg $ml^{-1}$, 3.125 mg $ml^{-1}$ and 1.562 mg $ml^{-1}$, prepared by serial dilution of stock solution (concentration of 25 mg $ml^{-1}$) was loaded in the wells to plot standard curve. Five µl of unknown sera was diluted to four times with 0.1 M Tris-HCl for SRID assay and then 10 µl of each sample was loaded in the wells. Lysoplate and IgG Plates were stained with 0.2% Coomassie Brilliant Blue (CBB) staining solution for 6 h and excess stain was removed with destaining solution. The diameters of the lysed/ precipitation zones around standards as well as unknown samples were measured with the help of Digital Vernier Calipers. The concentrations (after $\log_2 n$ transformation) of standards were regressed on diameter of the lysed/ precipitation zones around standards. The slope of the curve and intercept were determined. The serum lysozyme and IgG concentrations in the unknown sera samples were estimated using the regression equation: Y=bx+c; where, Y=Concentration of serum lysozyme or four times diluted serum IgG in unknown sera sample, b=Slope of regression equation, c=Intercept of regression equation and x=Diameter of the lysed/ precipitation zone around the sample.

### *2.5. Performance data recording*

Percent fertility and percent hatchability based on total egg set and fertile egg set were calculated for successive three hatches. Data on chick weight (in g), body weights (in g) at $1^{st}$, $2^{nd}$, $3^{rd}$, $4^{th}$, $6^{th}$, $8^{th}$, $12^{th}$, $16^{th}$, $20^{th}$ and $40^{th}$ weeks of age, age

at first egg (in days), egg weights (in g) at 28 and 40th weeks of age, part period egg production upto 40 weeks of age and mortality up to 40-weeks of age for first two hatches were recorded and analyzed.

*2.6. Statistical analysis*

The data on immunocompetence, growth and layer production traits was analyzed by least squares analysis of variance (Harvey, 1990) after pooling of data over all genotypes. Data on immunocompetence traits was analyzed by taking genotype and sex as fixed effects in the statistical model. Likewise, data on growth traits was analyzed by taking genotype, hatch and sex as main effects and chick weight as regression and genotype×sex interaction in the model. Data on layer production traits was analyzed by taking genotype and hatch as main effects and BW20 as regression effect. Critical differences between the least squares means and percent differences between the percent fertility, hatchability and mortality were assessed by Critical Difference (CD) test and Normal Deviate (ND) test, respectively at 5% level of significance.

## 3. Results and Discussion

*3.1. Immunocompetence traits*

Least squares analysis of variance indicated that all the five genotypes differed significantly ($p<0.05$) for HA titre, serum lysozyme and serum IgG concentrations (Table 1).

The least squares means of HA titre were 8.837±0.473, 10.393±0.473, 6.511±0.504, 6.012±0.455 and 5.789±0.452 in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens, respectively. The corresponding estimates of serum lysozyme concentration were 6.336±0.437, 5.174±0.428, 6.996±0.435, 5.692±0.404 and 6.000±0.472 µg $ml^{-1}$, and of serum IgG concentration were 6.597±0.361, 7.780±0.361, 7.749±0.390, 5.151±0.398 and 6.002±0.398 µg $µl^{-1}$ (Table 2). CD test revealed that $RIR^W$, CARI-Sonali and CARI-Debendra chicken genotypes did not significantly differed among themselves for HA titre though trend of LS means was $RIR^C$>$RIR^S$>$RIR^W$>CARI-Sonali>CARI-Debendra. Similarly non-significant differences were found for serum lysozyme concentration among $RIR^S$, $RIR^W$ and CARI-Debendra, among $RIR^C$, CARI-Sonali and CARI-Debendra, though its LS means had a trend of $RIR^W$>$RIR^S$>$RIR^C$>CARI-Debendra>CARI-Sonali. CD test also could not find any significant difference for serum IgG concentration between $RIR^C$ and $RIR^W$ strains, between $RIR^S$ and CARI-Debendra and between the crosses, though its least squares means showed a trend of $RIR^C$>$RIR^W$>$RIR^S$>CARI-Debendra>CARI-Sonali (Table 2). Pure strains demonstrated overall better immunocompetence than $F_1$ crosses. The significant and/or non-significant difference between breeds, strains and/ or crosses for various immunocompetence traits were reflected in earlier reports of Toro et al. (1997) and Saini et al. (2007). Immunocompetence traits in CARI-Debendra cross have recently been studied and a few significant association between IC traits and production traits have been reported (Das et al., 2014).

Table 1: Least squares analysis of variance of various immunocompetence traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| SoV | df | Mean sum of squares | | |
|---|---|---|---|---|
| | | Haemag-glutination (HA) titre | Serum lysozyme con-centration | Serum IgG concentra-tion |
| Genotypes | 4 | 306.244*** | 33.732* | 82.321*** |
| Sex | 1 | 0.070 | 2.300 | 0.655 |
| Remainder | 369 | 16.538 | 13.382 (351) | 9.509 (324) |

*$p<0.05$ and ***$p<0.001$; Figures within parentheses denote degrees of freedom

Chatterjee et al. (2007) found 8.79±1.44 and 7.60±1.78 HA titres (5 dpi), respectively in a non-inbred (NB) and full-sib mated (FS) populations of Dahlem Red chicken which corroborated with the present findings in $RIR^S$, CARI-Debendra, CARI-Sonali and $RIR^W$. Saini et al. (2007) found 4 dpi HA titre of 5.20 and 4.70 in RIR-C (CARI strain) and RIR-B (Bhubaneswar strain). Gupta et al. (2010) estimated HA titre in HSRBC and LSRBC lines of white Leghorn chicken as 8.06±0.22 and 7.87±0.26, respectively. Kumar et al. (2011) recorded 5 dpi HA titre in Aseel native chicken as 12.38±0.600. Some of the previous reports had contradictory estimates of serum lysozyme concentration. Kumar et al. (2011) estimated LS mean of serum lysozyme concentration as 3.42±0.19 µg $ml^{-1}$ in Aseel chicken. Ahrestani et al. (1987) estimated the serum IgG concentration as 7.53±0.22 mg $ml^{-1}$ in WLH chicken. Sivaraman et al. (2005) estimated the serum IgG concentration as 6.287±0.194 mg $ml^{-1}$ in a synthetic dam line (SDL) of broiler chickens. Saini et al. (2007) found serum IgG concentration of 2.03 µg $µl^{-1}$ in $RIR^C$ and 1.93 µg $µl^{-1}$ in $RIR^B$ strain. Singh et al. (2009) and Singh et al. (2010) estimated relatively higher serum IgG concentration in Kadaknath (10.07±0.20 µg $µl^{-1}$) and Aseel (10.61±0.25 mg $ml^{-1}$) chickens, respectively. The differences in various reports may be due to the different genetic backgrounds of the genotypes investigated.

*3.2. Performance traits*

*3.2.1. Percent fertility and hatchability*

The overall percent fertility and hatchability based on total egg set (TES) and fertile egg set (FES) in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens are presented in

Table 3.

$RIR^W$ demonstrated highest percent fertility followed by $RIR^C$>$RIR^S$>CARI-Sonali>CARI-Debendra. However, statistically, the differences among $RIR^W$, $RIR^C$ and $RIR^S$ were non- significant ($p$>0.05) by Normal Deviate (ND) test. The percent fertility values in present findings were lower than those reported earlier as 87.13, 87.04, 85.64 and 73.78% in $RIR^s$, $RIR^c$, CARI-Sonali and CARI-Debendra, respectively (CARI Annual Report, 2010-11). Fertility in $RIR^S$, $RIR^C$ and $RIR^W$ pure strains was found somewhat higher than that reported in RIR (71.6%) (Kamar et al., 1984). However, Kicka et al. (1978) observed highest (92.30%) fertility in Fayoumi×RIR cross as compared to Fayouni (89%) and RIR (77.9%).

Highest TES hatchability was observed in $RIR^C$, whereas highest FES hatchability was seen in CARI-Debendra chicken. However, statistically, the differences for TES hatchability between $RIR^C$ and $RIR^W$ and between $RIR^S$ and CARI-Sonali were non-significant ($p$>0.05) by ND test. Similarly, the differences for FES hatchability among CARI-Debendra, $RIR^C$ and $RIR^W$ and between $RIR^S$ and CARI-Sonali were also non-significant ($p$>0.05). Hatchability in RIR has been reported earlier also but with varied estimates, viz. 65.3% (Kamar et. al., 1984), 66.8% (Kicka et al., 1978) and 64.0±2.16% (Malago and Baitilwake, 2009). Present estimates of hatchability (FES) were close to the estimates reported in CARI Annual Report 2010-11 (2011) for $RIR^s$, $RIR^c$, CARI-Sonali (HR), CARI-Debendra (CD), which were 82.34, 85.18, 87.15 and 81.53%, respectively.

*3.2.2. Growth production traits*

All the five genotypes had significant effect on all the growth production traits (Table 4). Least squares means of various growth production traits are presented in Table 5.

Previous reports of Mohammed et al. (2005) (CW, BW2, BW4, BW6, BW8, BW12, BW16), Adebambo et al. (2006) (BW1), Chatterjee et al. (2007) (BW2, BW4, BW8, BW12, BW16), Malago and Baitilwake (2009) (CW), CARI Annual Report (2010-11) (BW20) were quite comparable to the present findings (Table 5). Least squares means of chick weight demonstrated a trend of $RIR^S$>CARI-Debendra>CARI-Sonali>$RIR^W$>$RIR^C$ (Table 5). At subsequent ages, CARI-Debendra demonstrated the highest body weight, which was mostly followed by CARI-Sonali, $RIR^S$, $RIR^W$ and $RIR^C$ by CD test (Table 5). Hatch and sex-effects on body weights were mostly significant (Table 4). Regression effect of chick weight on subsequent body weights was also significant (Table 4). Genotype×sex interaction effect was significant on body weight at 2nd week and then 8th week onwards (Table 4). At 2nd week CARI-Debendra-female showed highest body weight but subsequently CARI-Debendra-male were the heaviest at all ages (Table 5). Siegel (1962) reported that body weight at eight weeks of age was significantly affected by line effect in White Plymouth Rock chickens. Similar to the present findings, Mohammed et al. (2005) also obtained significant

Table 3: Fertility and hatchability in $RIR^S$, $RIR^C$, $RIR^W$ strains and CARI-Sonali and CARI-Debendra crosses

| Strains or crosses | Fertility (%) | Hatchability (%) | |
|---|---|---|---|
| | | Total egg set basis (TES) | Fertile egg set basis (FES) |
| $RIR^S$ | 75.86[a] | 57.46[b] | 75.65[b] |
| $RIR^C$ | 79.03[a] | 68.51[a] | 86.62[a] |
| $RIR^W$ | 79.34[a] | 67.80[a] | 85.27[a] |
| CARI-Sonali | 70.83[b] | 55.58[bc] | 78.44[b] |
| CARI-Debendra | 60.64[c] | 53.09[c] | 87.54[a] |

Percent value in each column with different superscripts differ significantly ($p$<0.05)

Table 2: Least squares means±standard errors of various immunocompetence traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| Factors | | Least squares means±standard errors | | |
|---|---|---|---|---|
| | | Haemagglutination (HA) titre | Serum lysozyme concentration (µg $ml^{-1}$) | Serum IgG concentration (µg $µl^{-1}$) |
| Genotypes | $RIR^S$ | 8.837±0.473[b] (74) | 6.336±0.437[ab] (70) | 6.597±0.361[b] (73) |
| | $RIR^C$ | 10.393±0.473[a] (74) | 5.174±0.428[c] (73) | 7.780±0.361[a] (73) |
| | $RIR^W$ | 6.511±0.504[c] (66) | 6.996±0.435[a] (72) | 7.749±0.390[a] (64) |
| | CARI-Sonali | 6.012±0.455[c] (80) | 5.692±0.404b[c] (82) | 5.151±0.398[c] (60) |
| | CARI-Debendra | 5.789±0.452[c] (81) | 6.000±0.472[abc] (60) | 6.002±0.398[bc] (60) |
| Sex | Male | 7.522±0.285 (205) | 6.121±0.266 (192) | 6.701±0.231 (179) |
| | Female | 7.494±0.314 (170) | 5.959±0.287 (165) | 6.610±0.253 (151) |

Different superscripts in a column for a factor denote significant ($p$<0.05) differences; Figures within parenthesis denote number of observations.

Table 4: Least squares analysis of variance of various growth traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| SoV | df | Mean sum of squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | BW1 | BW2 | BW3 | BW4 | BW6 | BW8 | BW12 | BW16 | BW20 |
| Genotypes | 4 | 963.7*** | 13387.5*** | 170356.5*** | 553402.9*** | 1574946.7*** | 3006920.8*** | 12515318.4*** | 35198225.8*** | 75602141.9*** | 29002792.1*** |
| Hatch | 1 | 1384.0*** | - | 153799.5*** | - | 596844.2*** | - | 1449575.5*** | 4391309.4*** | 123.7 | 120228.7£ |
| Sex | 1 | 87.0** | 41.3 | 1070.6* | 9319.9*** | 47507.6*** | 252658.3*** | 987734.0*** | 7380636.5*** | 33518886.2*** | - |
| Genotype × sex | 4 | - | 193.0$ | 1049.8** | 1624.2# | 3972.4¥ | 7095.0 | 48150.5*** | 279589.2*** | 1096065.1*** | - |
| RGS CW | 1 | - | 3946.4*** | 33948.3*** | 40140.8*** | 153424.0*** | 175001.1*** | 543931.5*** | 1985012.8*** | 2589555.4*** | 933663.7*** |
| Remainder | 2600 | 12.1 | 89.7 (938) | 280.3 (2595) | 770.3 (938) | 1723.1 (2492) | 4644.1 (938) | 11418.1 (1706) | 37800.3 (2310) | 124559.7 (2007) | 40434.2 (863) |

£$p<0.09$; #$p<0.08$; $$p<0.07$; ¥$p<0.06$; *$p<0.05$; **$p<0.01$; ***$p<0.001$; Figures within parenthesis denote degrees of freedom; RGS CW: regression of chick weight on the traits studied

differences for average body weight of different tester×line crosses between exotic testers, viz. RIR, Bovans, Egyptian Fayoumi cockerels and indigenous lines, viz. large Beladi, Bare-neck, Betwil hens. Adebambo et al. (2006) observed that the body weight were significantly affected by breed from 1st week onwards in Giriraja, Indian WLH, and Nigerian improved indigenous chicken genotypes in accordance to the present genotypic effect on growth performances.

*3.2.3. Layer production traits*

There had been significant effect of genotype on all the layer production traits (Table 6). Least squares means of various layer production traits are presented in Table 7.

CARI-Debendra pullets had significantly ($p<0.05$) higher housing body weight as compared to $RIR^S$>CARI-Sonali≈$RIR^W$>$RIR^C$ pullets. AFE was significantly better in CARI-Sonali followed by $RIR^S$<$RIR^W$<$RIR^C$≤CARI-Debendra. CARI-Debendra≈CARI-Sonali pullets had significantly ($p<0.05$) higher EW28 as compared to $RIR^S$>$RIR^C$, $RIR^S$≈$RIR^W$ and $RIR^W$≈$RIR^C$ pullets. CARI-Debendra pullets had significantly ($p<0.05$) higher BW40 as compared to $RIR^C$≈$RIR^W$≈CARI-Sonali≈$RIR^S$ pullets. CARI-Debendra≈CARI-Sonali pullets had significantly ($p<0.05$) higher EW40 as compared to $RIR^S$>$RIR^C$ and $RIR^S$≈$RIR^W$ and $RIR^W$≈$RIR^C$ pullets. CARI-Sonali pullets had significantly ($p<0.05$) higher EP40 as compared to $RIR^S$>$RIR^W$≈CARI-Debendra>$RIR^C$ pullets. Hatch effect on body weights was mostly significant. Regression effect of housing body weight (BW20) on all layer production traits was significant (Table 6). Considerable differences in egg weights between layer strains have also been reported earlier (Yoo et al., 1983; Merat , 1990; Malago and Baitilwake, 2009).

Present findings corroborated well with the previous reports of ranges of AFE from 194 to 214 in RIR male (strain-A) and female (strain-B) lines and 1440 to 1908 g BW40 in RIR male (strain-A) and female (strain-B) lines (Nwagu et al., 2007), 60.58±4.55 gm to 58.42±6.88 gm egg weights in RIR and crossbred (Malago and Baitilwake, 2009). According to the CARI Annual Report (2010-11), corresponding values of $RIR^s$, $RIR^c$ strains of 27th generation, CARI-Sonali and CARI-Debendra crosses were 140.58±0.30, 154.22±0.87, 149.82±18.66 and 154.27±0.87 days of AFE; 46.28±0.08, 44.18±0.13, 48.89±0.25 and 50.85±0.38 g of egg weight at 28th weeks of age; 1825.84±6.56, 1516.67±10.39, 1681.44±12.59 and 2928.39±31.20 g body weight at 40 weeks of age; 50.54±0.08, 48.63±0.12, 52.11±0.25 and 56.59±0.24g egg weight at 40th week of age; and 99.24±0.53, 69.83±0.85, 105.70±0.24 and 95.82±1.50 number of eggs up to 40 weeks of pullets' age. Chatterjee et al. (2010) recorded egg production

Table 5: Least squares means±standard errors of various growth traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| Factors | | Least squares means±standard errors (g) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | BW1 | BW2 | BW3 | BW4 | BW6 | BW8 | BW12 | BW16 | BW20 |
| Genotypes | $RIR^S$ | 37.50±0.11$^a$ (1101) | 56.79±0.68$^b$ (205) | 89.86±0.52$^c$ (1101) | 154.82±1.99$^c$ (205) | 196.77±1.30$^c$ (1059) | 352.15±4.87$^b$ (205) | 564.73±4.85$^c$ (648) | 976.21±6.30$^b$ (997) | 1446.63±12.72$^b$ (801) | 1589.74±10.25$^b$ (401) |
| | $RIR^C$ | 34.35±0.15$^c$ (513) | 52.73±0.62$^c$ (246) | 84.50±0.77$^d$ (513) | 142.61±1.82$^d$ (246) | 172.17±1.97$^e$ (479) | 276.34±4.46$^d$ (246) | 410.30±6.12$^e$ (331) | 747.33±9.70$^d$ (429) | 1088.38±8.23$^d$ (399) | 1204.75±20.02$^d$ (107) |
| | $RIR^W$ | 34.85±0.29$^c$ (144) | 51.38±1.14$^c$ (77) | 79.08±1.47$^e$ (144) | 138.44±3.33$^d$ (77) | 184.14±3.67$^d$ (142) | 322.55±8.17$^c$ (77) | 468.58±10.27$^d$ (120) | 912.87±19.02$^c$ (115) | 1319.17±35.91$^c$ (106) | 1442.18±32.80$^c$ (38) |
| | CARI-Sonali | 36.27±0.17$^b$ (423) | 58.15±0.66$^b$ (206) | 101.72±0.81$^b$ (423) | 172.81±1.94$^b$ (206) | 207.75±2.05$^b$ (412) | 357.97±4.75$^b$ (206) | 592.82±6.22$^b$ (305) | 959.39±9.74$^b$ (399) | 1452.99±18.46$^b$ (366) | 1482.72±15.58$^c$ (167) |
| | CARI-Debendra | 36.60±0.17$^b$ (426) | 72.69±0.65$^a$ (215) | 131.19±0.81$^a$ (426) | 267.75±1.91$^a$ (215) | 324.86±2.05$^a$ (412) | 587.77±4.69$^a$ (215) | 940.79±6.16$^a$ (314) | 1547.52±9.96$^a$ (382) | 2321.54±18.97$^a$ (347) | 2398.88±16.07$^a$ (157) |
| Hatches | 1 | 35.19±0.11$^b$ (1354) | - | 105.15±0.53$^a$ (1354) | - | 233.00±1.34$^a$ (1306) | - | 630.35±3.59$^a$ (1281) | 1073.41±6.57$^a$ (1233) | 1525.48±12.66$^a$ (1034) | 1611.59±11.27$^a$ (466) |
| | 2 | 36.65±0.11$^a$ (1253) | - | 89.39±0.54$^b$ (1253) | - | 201.28±1.36$^b$ (1198) | - | 560.54±5.27$^b$ (437) | 983.91±6.81$^b$ (1089) | 1526.00±13.01$^a$ (985) | 1635.72±11.78$^a$ (404) |
| Sex | Male | 36.10±0.10$^a$ (1381) | 58.58±0.46$^a$ (478) | 98.08±0.53$^a$ (1381) | 178.78±1.33$^a$ (478) | 222.60±1.34$^a$ (1321) | 397.56±3.27$^a$ (478) | 623.73±4.15$^a$ (890) | 1101.57±6.75$^a$ (1208) | 1688.45±12.78$^a$ (1047) | - |
| | Female | 35.73±0.11$^b$ (1226) | 58.12±0.51$^a$ (471) | 96.46±0.63$^b$ (1226) | 171.79±1.51$^b$(471) | 211.68±1.59$^b$ (1183) | 361.15±3.70$^b$ (471) | 567.16±4.77$^b$ (828) | 955.76±7.99$^b$ (1114) | 1363.03±15.22$^b$ (972) | - |
| Genotype × sex int. | $RIR^S$-male | - | 58.26±0.92 (109) | 90.60±0.71$^e$ (574) | 161.72±2.69 (109) | 202.60±1.80 (549) | 372.47±6.61 (109) | 584.03±6.30$^d$ (341) | 1043.14±8.73$^c$ (512) | 1639.10±18.08$^c$ (393) | - |
| | $RIR^S$-female | - | 55.32±0.98 (96) | 89.12±0.74$^e$ (527) | 147.92±2.86 (96) | 190.93±1.85 (510) | 331.83±7.03 (96) | 545.43±6.54$^f$ (307) | 909.28±8.90$^e$ (485) | 1254.16±17.61$^e$ (408) | - |
| | $RIR^C$-male | - | 53.34±0.88 (121) | 85.09±1.02$^f$ (282) | 148.07±2.57 (121) | 177.37±2.60 (264) | 289.90±6.31 (121) | 430.60±8.36$^h$ (170) | 785.94±12.93$^g$ (234) | 1186.46±24.29$^f$ (218) | - |
| | $RIR^C$-female | - | 52.11±0.86 (125) | 83.90±1.12$^f$ (231) | 137.15±2.51 (125) | 166.98±2.87 (215) | 262.78±6.15 (115) | 390.00±8.62$^i$ (161) | 708.71±14.12$^h$ (195) | 990.29±26.59$^g$ (181) | - |
| | $RIR^W$-male | - | 51.47±1.34 (50) | 80.08±1.74$^g$ (93) | 140.00±3.93 (50) | 187.06±4.34 (92) | 331.98±9.66 (50) | 492.71±12.13$^g$ (78) | 978.91±22.67$^d$ (74) | 1416.42±42.92$^d$ (68) | - |
| | $RIR^W$-female | - | 51.29±1.83 (27) | 78.09±2.35$^g$ (51) | 136.87±5.35 (27) | 181.22±5.88 (50) | 313.12±13.14 (27) | 444.45±16.52$^h$ (42) | 846.84±30.44$^f$ (41) | 1221.92±57.38$^f$ (38) | - |
| | CARI-Sonali-male | - | 58.32±0.94 (102) | 104.79±1.15$^c$ (213) | 176.64±2.75 (102) | 218.54±2.89 (207) | 378.58±6.75 (102) | 622.63±8.72$^c$ (153) | 1041.47±13.72$^c$ (201) | 1648.04±25.68$^c$ (189) | - |
| | CARI-Sonali-female | - | 57.99±0.93 (104) | 98.65±1.16$^d$ (210) | 168.98±2.72 (104) | 196.96±2.90 (205) | 337.36±6.68 (104) | 563.01±8.74$^e$ (152) | 877.32±13.83$^f$ (198) | 1257.93±26.55$^e$ (177) | - |
| | CARI-Debendra-male | - | 71.51±0.97 (96) | 129.82±1.13$^b$ (219) | 267.48±2.84 (96) | 327.40±2.88 (209) | 614.87±6.97 (96) | 988.66±8.85$^a$ (148) | 1658.38±14.23$^a$ (187) | 2552.22±26.41$^a$ (179) | - |
| | CARI-Debendra-female | - | 73.86±0.87 (119) | 132.55±1.17$^a$ (207) | 268.02±2.55 (119) | 322.32±2.92 (203) | 560.67±6.25 (119) | 892.92±8.40$^b$ (166) | 1436.66±13.94$^b$ (195) | 2090.85±27.26$^b$ (168) | - |

Different superscripts in a column for a factor denote significant ($p$<0.05) differences; Figures within parenthesis denote number of observations.

Table 6: Least squares analysis of variance of various layer production traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| Source of variation | df | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | AFE | EW28 | BW40 | EW40 | EP40 |
| Genotypes | 4 | 48057.3*** | 175.2*** | 1625333.9*** | 164.0*** | 64147.0*** |
| Hatch | 1 | 11536.5*** | 0.282 | 730.2 | 114.6*** | 4833.4*** |
| RGS HW | 1 | 29228.5*** | 183.6*** | 16315359.7*** | 366.0*** | 12001.7*** |
| Remainder | 863 | 233.9 | 15.9 | 30207.4 | 13.8 | 375.5 |

*$p$<0.05, **$p$<0.01, ***$p$<0.001; RGS HW denotes regression of housing body weight (at 20 weeks of age) on the layer traits studied

Table 7: Least squares means±standard errors of various layer production traits in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| Factors | | Number of Observations | Least squares means±standard errors | | | | |
|---|---|---|---|---|---|---|---|
| | | | AFE (days) | EW28 (g) | BW40 (g) | EW40 (g) | EP40 (number) |
| Genotypes | $RIR^S$ | 401 | 148.86± 0.78$^b$ | 44.98± 0.20$^b$ | 1744.78± 8.86$^c$ | 51.75± 0.19$^b$ | 96.45± 0.99$^b$ |
| | $RIR^C$ | 107 | 177.23± 1.92$^d$ | 43.46± 0.50$^c$ | 1775.74± 21.83$^{bc}$ | 50.45± 0.47$^c$ | 60.79± 2.43$^d$ |
| | $RIR^W$ | 38 | 169.33± 2.55$^c$ | 44.45± 0.67$^{bc}$ | 1766.87± 29.01$^c$ | 51.23± 0.62$^{bc}$ | 71.61± 3.24$^c$ |
| | CARI-Sonali | 167 | 135.06± 1.27$^a$ | 46.66± 0.33$^a$ | 1747.65± 14.44$^c$ | 53.46± 0.31$^a$ | 111.13± 1.61$^a$ |
| | CARI-Debendra | 157 | 177.73± 2.25$^d$ | 46.78± 0.59$^a$ | 2122.34± 25.54$^a$ | 53.52± 0.55$^a$ | 66.23± 2.85$^c$ |
| Hatch | 1 | 466 | 165.32± 0.85$^b$ | 45.29± 0.22$^a$ | 1830.55± 9.63$^a$ | 52.45± 0.21$^a$ | 78.86± 1.07$^b$ |
| | 2 | 404 | 157.96± 0.90$^a$ | 45.25± 0.23$^a$ | 1832.40± 10.21$^a$ | 51.71± 0.22$^b$ | 83.62± 1.14$^a$ |

Means within a factor having different superscripts differ significantly ($p$<0.05).

upto 40 weeks of age to be 44.68 for Kadaknath, 42.66 for Vanraja male line, 81.76 for Vanraja female line, 33.65 for Aseel, and 75.30 for Gramapriya female line. CARI-Sonali cross, $RIR^S$ pure strain and CARI-Debendra cross performed better than Vanraja female line and Grampriya female line also which are well known as best layers and which are being used for development of rural chicken varieties in India. $RIR^C$ and $RIR^W$ also performed better than Kadaknath, Aseel and Vanraja male line.

*3.2.4. Percent mortality*

Percent mortality at different stage viz., brooder, grower and layer, in different periods in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens were presented in Table 8.

It was evident in that CARI-Debendra chicks had least percent mortality in 0-7 days as compared to CARI-Sonali<$RIR^W$<$RIR^C$<$RIR^S$ chicks but it differed significantly ($p$<0.05) between $RIR^S$≈$RIR^C$ and CARI-Sonali≈CARI-Debendra. CARI-Sonali recorded the least percent mortality in 1-6 weeks' period preceded by CARI-Debendra<$RIR^C$<$RIR^S$<$RIR^W$ brooders but it differed significantly ($p$<0.05) between CARI-Sonali vs. CARI-Debendra≈$RIR^C$≈$RIR^S$ vs. $RIR^W$. $RIR^S$ had least percent mortality in 6-20 weeks period as compared to $RIR^C$<CARI-Sonali<CARI-Debendra<$RIR^W$ growers having significant ($p$<0.05) genotypic difference between $RIR^S$≈$RIR^C$≈CARI-Sonali vs. $RIR^W$. $RIR^W$ had no mortality and $RIR^S$ had least percent mortality in 20-40 weeks' period as compared to CARI-Debendra<$RIR^C$<CARI-Sonali layers but it differed significantly ($p$<0.05) between $RIR^S$≈CARI-Debendra≈$RIR^C$≈CARI-Sonali vs. $RIR^W$. Mortality in various genotypes was well within the range of normal mortality observed in intensive rearing, except in few cases. Hutt (1938) also reported a lower mortality in upgraded birds compared to indigenous stock of improved birds. Almost similar range of mortality in various chicken germplasm has been reported earlier (Adebambo et al., 2006; Malago and Baitilwake, 2009).

Table 8: Percent mortality in $RIR^S$, $RIR^C$, $RIR^W$, CARI-Sonali and CARI-Debendra chickens

| Strains or crosses | Period | Mortality (%) | | |
|---|---|---|---|---|
| | | Brooders (both sexes) | Growers (both sexes) | Layers (pullets) |
| | 0-7 days | 1-6 weeks | 6-20 weeks | 20-40 weeks |
| $RIR^S$ | $5.14^b$ | $4.80^b$ | $5.60^a$ | $7.73^b$ |
| $RIR^C$ | $4.42^b$ | $4.62^b$ | $6.06^a$ | $9.23^b$ |
| $RIR^W$ | $4.32^{ab}$ | $9.03^c$ | $13.48^b$ | $0.0^a$ |
| CARI-Sonali | $2.06^a$ | $1.17^a$ | $6.38^a$ | $10.05^b$ |
| CARI-Debendra | $1.61^a$ | $3.73^b$ | $6.54^a$ | $8.19^b$ |

Values in a column with different superscripts differ significantly ($p<0.05$).

## 4. Conclusion

RIR pure strains were better than their crosses for immunocompetence status and traits were not influenced by sex. RIR-white strain demonstrated highest percent fertility of eggs followed by other pure strains and crosses, whereas the highest percent TES hatchability was in RIR control strain. CARI-Debendra cross grew faster than CARI-Sonali and RIR strains, males being heaviest at all ages. CARI-Sonali pullets matured at the earliest age and produced highest numbers of eggs as compared to RIR selected and white strains, CARI-Debendra cross and RIR control strain. Pullets of crosses laid larger sized eggs than pure strains. Layer production performances were influenced by genotype, sex and hatch. Chick weight and housing body weight played significant role on subsequent performance traits. The information generated in this investigation may be useful in chalking out programs for simultaneous genetic improvement in the production traits along with immunocompetence traits.

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