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Research Article

Evaluation of Production Traits in Gramapriya Female Line Chicken Under Intensive System of Rearing

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Abstract

The present study was aimed at evaluating the performance of Gramapriya female line (PD-3) chicken reared under intensive system for production. Data collected on 619 hens, produced from 50 sires and 250 dams in a pedigreed full-sib mating in five hatches during 9th generation, were utilized for the present investigation at ICAR- Directorate of Poultry Research, Hyderabad. Hens attained sexual maturity (ASM) at 153.88 ± 1.38days. The body weight of hens (BW) at 20, 40, 52 and 64 weeks was 1539.86 ± 15.08, 1733.18 ± 23.22, 1901.89 ± 26.34 and 1934.56 ± 29.82g respectively. The egg weight varied from 53.30 ± 0.35 g to 60.23 ± 0.46 g from 28 to 64 weeks and exhibited moderate to high heritability. The total egg production (EP) to 64 weeks was 204.02 ± 3.96 with low to moderate heritability while egg mass up to 64 weeks was 12368.9 ± 4.06 g. The correlation coefficients revealed positive correlation between body weight, egg weight and egg mass. However, correlation between egg weight and egg production was negative and varied from low to high in magnitude. A similar trend was observed in correlation between body weight, egg production and age at sexual maturity. Based on results of the study, it was concluded that the PD-3 (Gramapriya female line) population has got reasonable variability in production traits. The gradual improvement in these production traits in parent line will improve the performance in terminal cross "Gramapriya" with respect to egg production and egg weight which ultimately benefits the farmers.

Keywords: Correlation; Gramapriya; Heritability; Production Traits

Introduction

Backyard poultry farming is an ancient practice carried out by poor farmers and tribes in rural India. It has been a proven tool for alleviation of poverty in rural areas and eliminating malnutrition among the local people. Presently, backyard poultry farming contributes about 17.8% of total egg production (114.38 billion) in India [1]. It is low input or no input activity which mainly depends on scavenging or by natural feeding and little supplementary feeding, night shelter and minimum health care practices [2]. The rural chicken varieties have superior characteristics both in terms of qualitative traits like multi-coloured patterns, meat quality, majestic gait, appearance and quantitative traits such as lean body weights, longer shanks, relatively higher disease resistance, and hardiness [3]. Consumers are ready to pay higher prices for these poultry products due to their perceived health benefits.

Gramapriya is one of the dual-purpose multi-coloured varieties developed by crossing between PD-6 male × PD-3 female lines and propagated by the Directorate of Poultry Research for backyard farming has been adopted successfully across the country. Gramapriya is a dual-purpose coloured bird that has significantly contributed to rural poultry in terms of meat and eggs. Birds attain an age at sexual maturity around 175 days. They weigh 1.2 to 1.5 kg at 3 months of age and lay about 160-180 eggs in 72 weeks [3]. In context of above, present study was conducted to evaluate the performance of Gramapriya female line chicken for production and egg quality traits.

Materials and Methods

Experimental population

Gramapriya female line (PD-3) is a pure line evolved from Dahlem Red chicken and it is a promising egg-type chicken variety. A total of 619 adult hens from five hatches were utilized for the present study. The chicks were reared under standard management conditions from birth to six weeks of age. During this period, chicks were provided with a decreasing temperature schedule starting from 34 ± 1ºC during the first week which was gradually reduced to 26 ± 1ºC by the third week of age. After the brooding period, chicks were maintained at room temperature. The chicks were fed *ad-libitum* with layer chick diet (2800 kcal/kg ME; 18% CP) based on maize- soybean meal during 0-8 weeks of age. Hens (619) were reared up to 16 weeks of age in grower house on deep litter floor and then hens were housed in individual cages with one and a half square feet of floor space and fitted with automated drinkers. The birds were fed with layer grower diet (2700 kcal/kg ME; 17% CP) from 9 to 20 weeks of age and in layer breeder ration (2600 kcal/kg ME; 16% CP) from 21st week to the end of the study period. The birds were vaccinated against Marek's disease (day 1), Newcastle disease, Lasota strain (day 7and 30), Infectious bursal disease (day 14 and 26), fowl pox (6th week), Newcastle disease-R2B killed (9th week) and IB (12-13 weeks) and ND-R2B killed booster (18th week).

Statistical analysis

Data were analysed using least square technique [4] using a SPSS 12.0 to know the effect of the hatch on traits studied. Hatch corrected data were utilized for the estimation of heritability by variance component analysis [5]. The genetic and phenotypic correlations between various traits were estimated from variance-covariance component analysis [6].

Results and Discussion

Results of economic traits like bodyweight, egg production, egg weight and egg mass are given in (Table 1). Adult body weight plays a crucial role in quantum of egg production. Optimum body weight should be attained before onset of egg production as which was clearly observed in this study. Body weight at 20 weeks was 1539.86 ± 15.08g which was in standard range as that of reported in Gramapriya female line [7], in Vanaraja [8], in Nandanam Chicken IV [9].

Steady increase in bodyweight was observed in bodyweights recorded at 40 and 52 weeks which were comparable with Dahlem Red and Dahlem Red x Desi [10], in Aseel [11], Kamarupa chicken [12]. However, there was slight increase in body weight from 52 to 64 week of age which might be due to better feed intake at later stages of production cycle. Generally, body weight of PD-3 chicken was higher than desi breeds and lower than that of synthetic backyard varieties evolved by using exotic broiler breeds as one of the parent lines. Hence Gramapriya chicken is a promising variety for meat which can satisfy hunger of rural household. Low to moderate h^2estimates for body weight were observed at 20 and 40 weeks while, higher h^2 observed during 52 and 64 weeks of age which was higher than in Naked neck chicken [13].

Age at sexual maturity plays a significant role in determining future of egg number of laying flock as less the ASM, more will be the egg production. ASM (153.88 ± 1.38 days) in this study was reasonable as PD-3 line was rural female line. Similar results were obtained in Dwarf chicken [14], Gramapriya chicken under different rearing systems [15], Vanaraja [16] respectively. Lower ASM was observed in White Nicobari [17], White Leghorn and Brown egg Dwarf chicken [18], and Gramapriya birds reared under intensive system [19], whereas higher age of sexual maturity was found by in Aseel and Kadaknath [20] and Horro chicken [21]. Several factors have influence on ASM namely, genetic makeup of variety or breed, lighting and feeding schedule followed during pullet stage. Gramapriya chicken attains early age of sexual maturity compared to native chicken breeds and hence it is ideal for backyard poultry farming.

Egg production at 40 weeks (100.41 ± 1.91) was higher compared to Miri (33.59 ± 0.99 days) [7], Vanaraja (52.8 ± 0.05) [22], Naked neck chicken (64.18 ± 0.13) [13], CARI-Nirbheek (59.94 ± 0.41) [23]. Higher EP 52 was reported in Black Nicobar Chicken (192.14) [17], Giriraja (204.34 ± 0.59) [24], in IWH (188.8 ± 1.12) and IWK (167.4 ± 1.24) [25] strains of chicken compared to PD-3 chicken (160.90 ± 2.77) in our present study. Higher EP 64 was recorded in IWN (237.13 ± 0.10) and IWP (246.4 ± 0.04) [26] strains of chicken than present findings (204.02 ± 3.96) in PD-3 chicken. Apart from genetic factors, management, nutrition and feeding plays significant role in egg production. The mean egg production in Gramapriya chicken might be attributable to the genetic makeup as it has layer breeder inheritance, in which the production potential is comparatively high.

Traits	LSMs	Heritability		
		h^2_S	h^2_D	h^2_{S+D}
ASM (d)	153.88 ± 1.38	0.32 ± 0.14	0.32 ± 0.17	0.32 ± 0.11
Body weight (g)				
BW 20	1539.86 ± 15.08	0.45 ± 0.14	0.23 ± 0.16	0.34 ± 0.11
BW 40	1733.18 ± 23.22	0.45 ± 0.14	0.25 ± 0.13	0.10 ± 0.10
BW 52	1901.89 ± 26.34	0.89 ± 0.25	0.54 ± 0.16	0.71 ± 0.15
BW 64	1934.56 ± 29.82	0.52 ± 0.19	0.74 ± 0.19	0.63 ± 0.13
Egg Production (No)				
EP 40	100.41 ± 1.91	0.34 ± 0.14	0.20 ± 0.16	0.27 ± 0.11
EP 52	160.90 ± 2.77	0.27 ± 0.13	0.33 ± 0.17	0.30 ± 0.11
EP 64	204.02 ± 3.96	0.45 ± 0.16	0.32 ± 0.16	0.39 ± 0.12
Egg weight (g)				
EW 28	53.30 ± 0.35	0.60 ± 0.20	0.54 ± 0.17	0.57 ± 0.15
EW 40	55.58 ± 0.42	0.73 ± 0.21	0.18 ± 0.14	0.45 ± 0.14
EW 52	58.51 ± 0.41	0.72 ± 0.22	0.41 ± 0.16	0.57 ± 0.14
EW 64	60.23 ± 0.46	-	-	-
Egg mass				
EM 40	5547.33 ± 1.74	0.25 ± 0.12	0.20 ± 0.16	0.23 ± 0.10
EM 52	9418.45 ± 2.64	0.13 ± 0.10	0.17 ± 0.17	0.15 ± 0.10
EM 64	12368.9 ± 4.06	0.40 ± 0.15	0.28 ± 0.16	0.34 ± 0.11

Table 1: Least square means of body weight and production traits and their heritability estimates in Gramapriya (PD-3) female line chicken.

PD-3 female line chicken laid bigger size eggs (53.30 ± 0.35 g) as early at 28 weeks. Increased egg size at younger stages of production cycle has a positive role in economics as more good quality chicks will be available for sale. Apart from breeder's economics, consumers always prefer to go for bigger size eggs. Egg weight at 40 weeks of age was similar with results obtained in PD1 x PB-2 [27], while lower egg weights were reported in Himasamridhi [28] and Vanaraja [29,30]. Higher egg weight was observed in a cross between PD1 and PB-2(63.04 ± 0.62g) [27] when compared to egg weights (60.23 ± 0.46g) recorded at 64 weeks of age. Increase in egg weights at different ages in the present study might be due to increase in bodyweight, ASM and feeding pattern during laying period.

Egg mass plays a critical role in selection of flock for both egg production and egg weight. In the present study egg mass obtained at 40, 52 and 64 weeks were 5547.33 ± 1.74g, 9418.45 ± 2.64g and 12368.9 ± 4.06 g respectively. Higher egg mass is an indication of higher egg production and egg weight. Hence both egg production and egg weight can be improved by taking egg mass as selection criteria.

Genetic parameters

Heritability gives an idea to the breeders about the presence of additive genetic variance, which is transmitted to the offspring from their parents. The overall heritability estimates of body weight at 20, 40, 52 and 64 weeks of age were 0.343 ± 0.117, 0.104 ± 0.101, 0.718 ± 0.153, 0.634 ± 0.139. The estimates of heritability of body weight at different ages varied from low to high in the present study. The h^2_S estimates for BW 20, BW 40, BW 52 were moderate to higher than other heritability components, while h^2_D of BW64 exhibited a higher value than h^2_S. Values were similar to the value reported in Sex-linked Dwarf chicken [31]. Lower heritability values were reported in Vanaraja male line [32]and Rajasri chicken [33] respectively at 20 weeks of age, while higher heritability estimates were obtained in Vanaraja male [34] and Vanaraja female line [35] respectively.

The h^2_{S+D} estimates for 40-week body weight were comparable with the findings on research study on IWH chicken [36] and in PD1 chicken [27]. However higher heritability estimates were obtained by other authors [14,35,37]. The heritability estimates for sire, dam and sire + dam components for body weight at 52 weeks were moderate to higher values than that of values reported by authors in literature. However similar value for h^2_S was obtained for IWK [38]. The Heritability estimates for body weight at 64 weeks of all the three components were significantly higher than the values reported in Naked Neck chicken [38]. As body weight being a highly heritable trait, h^2 values were higher irrespective of age of flock. Variations in heritability estimates are affected by breed, environmental factors and sampling errors during the research study. Some non-genetic factors like poor management practices and changes in environment increase residual variance and hence decrease heritability estimates.

Egg production is one of the important economic traits that determine the profitability of backyard poultry farming. The heritability estimates for combined sire and dam components were 0.277 ± 0.110, 0.307 ± 0.113, 0.391 ± 0.120 for egg production up to 40, 52 and 64 weeks of age. Similar values for EP 40 were reported in IWK [39]. Lower heritability estimates than the present study was reported by some authors [32,35,40], whereas higher heritability values were obtained in RIR [41]. Heritability estimates for egg production were low due to less additive genetic variance in the flock.

The heritability estimates for egg production up to 52 weeks was in close agreement with estimates reported by authors [31,35,42], while heritability estimates for EP 64 were found to be higher when compared with values in Naked Neck chicken [13]. Egg weights exhibited moderate heritability ranging from 0.459 ± 0.14 to 0.575 ± 0.15 and these values were found to be in a closer range reported in white leghorn control [38,39] while other authors reported lower value than the present study. Variations in egg weight may be due to breed differences, type of birds and bodyweight of birds [35]. Heritability values for BW 52 were found to be higher than values reported in white leghorn [38] and Naked neck chicken [13].

Correlation among economic traits is an indispensable part of any breeding program, as the direction and magnitude of these correlations would determine the genetic changes in correlated traits. The correlation coefficient of between body weights was positive at different ages and significantly higher values were obtained 0.67 ± 0.10 (BW 20 with BW 52), 0.78 ± 0.07 (BW 20 with BW 64) and 0.87 ± 0.03 (BW 52 with BW 64). This may be revealed that birds heavier at early age were also heavier at later age due to the pleiotropic actions of genes controlling bodyweights [26]. The correlation between BW 40 and EW 40 was similar to results obtained by in control group [36,39] whereas, higher values were obtained in Dwarf chicken [14] and in Naked Neck [13], while lower values are reported in IWI [36,38]. There was a positive association between body weights and egg weights as age advanced, heavier birds laid heavier eggs. The correlation coefficient between BW 40 and EP 40 was similar in IWK [39], while lower values are obtained for IWI [38] and IWK [36].

The genetic correlation between ASM with BW 40 was in close agreement with findings in Naked neck chicken [13], White leghorn [36], and positively correlated to bodyweight at different ages. Similarly, there was positive correlation between ASM and egg weights at different ages with low to moderate values. Closer values were reported in IWI [38,39]. There was negative association of ASM

	ASM	BW20	BW40	BW52	BW64	EW28	EW40	EW52	EW64	EP40	EP52	EP64	EM40	EM52	EM64
ASM	-	0.10	0.30	0.43	0.21	0.68	0.35	0.57	0.23	-0.86	-0.66	-0.62	-0.74	-0.44	-0.51
BW20	-0.16	-	-	0.67	0.78	0.39	0.59	0.29	0.39	-0.03	-0.02	0.02	0.27	0.17	0.20
BW40	0.16	-	-	0.25	0.18	-	0.61	0.23	0.05	-0.51	-0.27	-0.38	0.57	0.29	0.39
BW52	0.17	0.35	0.09	-	0.87	0.48	0.50	0.51	0.52	-0.56	-0.50	-0.44	-0.35	-	-
BW64	0.10	0.35	0.07	0.69	-	0.42	0.56	0.44	0.42	-0.13	-0.09	-0.03	0.15	0.21	0.15
EW28	0.26	0.24	-	0.28	0.26	-	0.93	0.78	0.64	-0.77	-0.65	-0.57	-0.34	-0.28	-0.24
EW40	0.20	0.19	0.44	0.29	0.27	0.58	-	0.95	0.80	-0.42	-0.31	-0.21	0.06	0.32	0.18
EW52	0.16	0.18	0.09	0.29	0.24	0.58	0.66	-	0.76	-0.66	-0.65	-0.50	-0.21	-0.10	-0.12
EW64	0.08	0.14	0.04	0.31	0.26	0.43	0.46	0.47	-	-0.47	-0.38	-0.25	-0.08	0.05	0.24
EP40	-0.62	0.14	-0.41	-0.24	-0.12	-0.23	-0.26	-0.24	-0.12	-	0.96	0.81	0.87	0.76	0.82
EP52	-0.46	0.10	-0.12	-0.24	-0.11	-0.18	-0.22	-0.19	-0.11	0.86	-	0.71	0.88	0.82	0.83
EP64	-0.37	0.10	-0.19	-0.17	-0.06	-0.11	-0.11	-0.10	-0.07	0.72	0.51	-	-	0.96	0.87
EM40	-0.55	0.23	0.02	-0.13	-0.02	-0.0	0.12	-0.01	0.05	0.92	0.79	-	-	-	-
EM52	-0.38	0.19	0.01	-	-0.11	0.07	0.03	0.22	0.08	0.75	0.90	0.83	-	-	-
EM64	-0.31	0.18	0.05	-	0.03	0.06	0.07	0.08	0.31	0.63	0.80	0.41	-	-	-

Table 2: Genetic (above the diagonal) and phenotypic (below the diagonal) correlations for production traits in Gramapriya female line chicken.

[ASM, age at sexual maturity; BW20, body weight at 40 weeks;BW52, body weight at 52 weeks; BW 64, bodyweight at 64 weeks; EW 28, egg weight at 28 weeks; EW 40, egg weight at 40 weeks; EW 52 egg weight at 52 weeks; EW 64, egg weight at 64 weeks; EP 40, egg production at 40 weeks; EP 52, egg production at 52 weeks; EP 64, egg production at 64 weeks; EM 40, egg mass at 40 weeks; EM 52, egg mass at 52 weeks; EM 64, egg mass at 64 weeks].

with egg production and egg mass. Higher values were obtained for genetic correlation between ASM and egg production at different ages of production which suggests that late age of sexual maturity results in less egg production. The values obtained were comparatively higher than reported in Dwarf chicken [14] and in IWK [39]. Similar association was found in the correlation between ASM, and egg mass as early matured birds lay small-sized eggs which results in lower egg mass.

Egg production at all ages were negatively correlated with ASM, bodyweight, egg weight and positively related with egg mass. The genetic correlation between EP 40 and EW 40 obtained in the present study was moderate and negative, which was comparable with values reported in PD1 [27]. Lower values are reported in IWI [38] and in the White Leghorn control group [39]. The negative association between ASM and egg production implies that improvement in egg production will be result in early sexual maturity of birds [26].

The genotypic correlation between BW 52 and EW 52 was 0.518 ± 0.12 which was similar to values reported by [13,38], while lower values for correlation in IWI and IWK [36]. Phenotypic correlation values between BW 52 and EW 52 were found to be slightly higher than the values reported by the above authors. The positive trend seen in both phenotypic and genotypic correlation reveals that heavier birds lay large size eggs. Meanwhile, the genetic correlation between BW 52 and EP 52 was of moderate value and negative in direction, which was less than the value [13]. The genetic and phenotypic correlation between BW 64 and EW 64 was found to be moderate and positive. The value obtained was slightly lower than the value reported in Naked Neck chicken [13]. Phenotypic correlation for the same was low and negative while the same author reported moderate and positive values. Whereas genetic and phenotypic correlation among BW 64 and EP 64 was very low and negative than the value reported [13]. Genetic and Phenotypic correlation between EW 64 and EP 64 was negative and very low compared with values reported in Naked neck chicken [13] and in RIR pure strain [43]. This clearly indicates that improvement in egg weight will result in reduced egg production. Hence, accurate estimation of correlation coefficients helps the breeder in selecting the traits of significant positive association for simultaneous improvement of traits.

Conclusion

The study revealed that the PD-3 population has genetic variability in production traits studied with a reasonable additive genetic variance which will be transferred to offspring. The improvement in primary traits in pure lines will lead to increased performance in the terminal crosses, which is beneficial to the farmers.

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Bibliography

1. BAHS. Basic Animal Husbandry Statistics. Department of Animal Husbandry and Dairying. Ministry of Fisheries, Animal Husbandry and Dairying, Government of India (2020).
2. Sharma RP and Chatterjee RN. "Backyard poultry farming and rural food security". *Indian Farming* 59 (2009): 36-37, 48.
3. Rajkumar U., *et al*. "Backyard poultry farming for sustained production and enhanced nutritional and livelihood security with special reference to India: a review". *Tropical Animal Health and Production* 53.1 (2021): 1-13.
4. Harvey W R. "Users guide for PC-2 version of LSM LMW mixed model least- squares and maximum likelihood computer programme". W. R. Harvey. Columbus, OH (1990).
5. King S C and Henderson C R. "Variance component analysis in heritability studies". *Indian Journal of Poultry Science* 33 (1954): 147-154.
6. Becker WA. "Manual of procedures in Quantitative Genetics". Washington State University, Pullman, Washington (1975).
7. Haunshi S., *et al*. "Production performance of indigenous chicken of northeastern region and improved varieties developed for backyard farming". *Indian Journal of Animal Sciences* 799 (2009): 901.
8. Ramana D B V., *et al*. "Performance of Vanaraja birds as backyard poultry". *Indian Veterinary Journal* 875 (2010): 517-518.
9. Chitra P. "Comparative study of Nandanam chicken IV (Rhodo White chicken) and desi chicken rearing under backyard system in rural areas of Salem district of Tamil Nadu". *International Journal of Science, Environment and Technology* 8 (2019): 1049-1053.
10. Jha D K., *et al*. "Comparative evaluation of Dahlem red and desi crosses chicken reared under intensive system of poultry management". *Journal of Agricultural Technology* 96 (2013b): 1405-1410.
11. Dalal DS., *et al*. "Genetic evaluation of growth, production and reproduction traits in Aseel and Kadaknath chickens in agro-climatic conditions of northern India". *Biological Rhythm Research* (2019): 1-10.
12. Sharma R P and Chatterjee R N. "Backyard poultry farming and rural food security". *Indian Farming* 59 (2009): 36-37, 48.
13. Rajkumar U., *et al*. "Genetic architecture of growth and production parameters in a laying cycle of 72 weeks in naked neck chickens". *Indian Journal of Animal Sciences* 82 6 (2012b): 615.
14. Rajkumar U., *et al*. "Evaluation of dwarf gene linked parameters in chicken". *The Indian Veterinary Journal* 87.10 (2011a): 991-994.
15. Patel N., *et al*. "Performance of Gramapriya poultry birds under different systems of management". *Journal of Agricultural Technology* 97 (2013): 1769-1774.
16. Pathak P K and Nath BG. "Rural poultry farming with improved breed of backyard chicken". *Journal of World Poultry Research* 3 (2013): 24-27.
17. Kundu A., *et al*. "Production performance of indigenous Nicobari fowls, Vanaraja and their various F1 crosses under hot and humid climate of Andaman and Nicobar Islands, India". *Indian Journal of Animal Sciences* 852 (2015): 172-177.
18. Yi G., *et al*. "Genetic analysis for dynamic changes of egg weight in 2 chicken lines". *Indian Journal Poultry Science* 93.12 (2014): 2963-2969.
19. Giri S C and Sahoo SK. "Performance of Gramapriya chickens under extensive and intensive systems of management". *Indian Veterinary Journal* 89.1 (2012): 52.
20. Haunshi S., *et al*. "Characterization of two Indian native chicken breeds for production, egg and semen quality, and welfare traits". *Poultry Science* 902 (2011): 314-320.
21. Dana N., *et al*. "Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia". *Tropical Animal Health and Production* 43.1 (2011): 21-28.
22. Padhi M K and Chatterjee R N. "Inheritance of body weight, shank length and production traits in PD1 (Vanaraja male line)". *Indian Journal of Poultry Science* 47.3 (2012): 269-273.
23. Khadda B S., *et al*. "Production performance and economics of CARI Nirbheek chicken for backyard farming under semi-arid ecosystem in central Gujarat, India". *Indian Journal Animal Research* 51.2 (2015): 382-386.
24. Somu Y. "Comparative study of Giriraja and Desi birds under backyard system of rearing in farmers field". *Veterinary Science Research Journal* 6 (2015): 100-102.
25. Haunshi S., *et al*. "Genetic characterization of layer germplasm evolved by AICRP on poultry breeding ICAR" (2016).
26. Veeramani P., *et al*. *International Journal of Veterinary Science* (2012).
27. Padhi MK., *et al*. "Evaluation of four different crossbreds developed for backyard poultry farming under intensive system". *Indian Journal of Animal Sciences* 859 (2015b): 985-990.

28. Sankhyan V and Thakur Y P. "Development and evaluation of location specific chicken variety for improving rural poultry farming in western Himalayan state of Himachal Pradesh, India". In Proceedings of the World Congress on Genetics Applied to Livestock Production, Species–Avian 2:87.

29. Islam R., *et al*. "Comparative performance of Vanaraja and Indigenous chicken under backyard system of rearing". *Journal of Poultry Science and Technology* 2.1 (2014): 22-25.

30. Sarma M., *et al*. "Comparative Assessment of Performances of Vanaraja, Kamrupa and Desi Chicken Reared by Tribal Community of Lower Brahmaputra Valley Zone of Assam". *International Journal Current Microbiology Applied Science* 98 (2020): 2422-2428.

31. Rajkumar U., *et al*. "Inheritance of growth and production traits in sex linked dwarf chicken in a laying cycle of 64 weeks". *Indian Journal of Poultry Science* 46.2 (2011b): 143-147.

32. Padhi MK., *et al*. "Evaluation of Vanaraja male line PD1 for different production and egg quality traits". *Indian Journal of Animal Sciences* 85.6 (2015a).

33. Reddy VV., *et al*. "Genetic analysis of growth traits in Rajasri variety of backyard chicken". *Indian Journal of Poultry Science* 51.3 (2016): 342-345.

34. Suresh K. "Genetic Evaluation of Growth and Production Traits in Vanaraja Male Line (PD1) Chicken". M.V.Sc. Thesis, Sri P.V. Narsimha Rao Telangana Veterinary University, Hyderabad (2018).

35. Rajkumar U., *et al*. "Evaluation of Vanaraja female line chicken for growth, production, carcass and egg quality traits". *The Indian Journal of Animal Sciences* 90.4 (2020).

36. Sreenivas D., *et al*. "Genetic analysis of egg quality traits in White Leghorn chicken". *Veterinary World* 6.5 (2013): 263.

37. Padhi MK., *et al*. "Evaluation of Vanaraja male line PD1 for different production and egg quality traits" (2015).

38. Jayalaxmi P. "Genetic analysis of various productive immunocompetance traits in White Leghorn under selection". Ph.D. Thesis, Sri Venkateshwara Veterinary University, Tirupati (2008).

39. Chatterjee RN., *et al*. "Inheritance of important economic traits in three pure lines and a control population of White Leghorn". *Indian Journal of Animal Sciences* 78.1 (2008): 75-79.

40. Hussain MD., *et al*. "Evaluation and genetic analysis of egg production and egg quality traits in Rajasri birds". *Indian Journal of Poultry Science* (2017).

41. Jilani M H., *et al*. "Genetic studies on some economic traits of Rhode Island Red". *Indian Journal of Poultry Science* 421 (2007): 76-78.

42. Niranjan M., *et al*. "Evaluation of performance of PD-2 line up to 52 weeks of age". In: Proc. of Xxviii Annual conference and International Symposium of Indian Poultry Science Association (2011): 33.

43. Kumar S. "Genetic analysis of growth, production and reproduction traits after long-term selection in Rhode Island Red chicken". *Indian Journal of Animal Research* (2015).