Status of Genetic Resources of Chicken Evolved at ICAR-DPR








ICAR-Directorate of Poultry Research

Rajendranagar, Hyderabad - 500 030

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Preface

During annual meeting of Institute Research Committee-2013 while going through the presentation of progress reports of various research projects, need for the compilation of information on progress made in the improvement of chicken germplasm of the Institute over several generations was felt. That need prompted us to compile all the information related to chicken germplasm improvement undertaken at ICAR-Directorate of Poultry Research, Hyderabad.

This book dwells on the origin of various lines, how they evolved over a period of time, the criterion of selection employed in each line and how they changed over a period of time, fertility, hatchability, number of chicks hatched in each generation, number of parents (sires and dams) used for regeneration, rate of inbreeding, effective population size, performance with respect to various growth and production traits, the phenotypic response, etc. Genetic parameters such as heritability and correlations for some of the lines were also included. This compilation was made by going through the Annual Reports of the Directorate of Poultry Research. The information belonging to each and every line/breed was compiled from the Annual Reports published during 1988- 2014 and other special reports.

Authors hope that this book will become handy for breeders and geneticists to understand how various lines behaved over a period of time, helps in formulating breeding programs and also to avoid duplication of work in future while taking up new projects.

We acknowledge the contribution of earlier scientists (breeders) whose work previously published in the Annual Reports of the Institute is cited in this book. List of various research projects on breeding undertaken in the Institute over a period of time and their respective principal investigators is also included in the book to acknowledge their contribution.

Authors dedicate this work to esteemed former directors of our Institute; Dr. S.C. Mohapatra, Dr. V.R. Sadagopan, Dr. V. Ayyagari, Dr. G. Shyam Sunder and Dr. R.P. Sharma.

We are grateful to all the staff of our Institute for their whole hearted support and cooperation in compilation of this manuscript.

Hyderabad 2015 Authors

1. Overview of Directorate of Poultry Research

Directorate of Poultry Research was established on 1st March, 1988 as Project Directorate on Poultry. The main objective of this Directorate as envisaged in the VII plan document was to coordinate and monitor the progress of All India Coordinated Research Projects (AICRP) on Poultry Breeding, Poultry Nutrition and Poultry Housing and Management besides other research projects sponsored by Indian Council of Agricultural Research (ICAR) in different disciplines of Poultry. This Institute started its operation in 30 acres of land and 13 poultry sheds provided by the then Andhra Pradesh Agricultural University, Rajendranagar to ICAR on 99 years lease. Initially, nucleus stock production unit was established in the Directorate in March 1988. Subsequently, control population units of HAU, Hisar and UAS, Bangalore were transferred to Directorate with effect from 1st April 1990 as per the recommendation of the Mid-term Appraisal Committee and thus work on control population was initiated at the Directorate. The evaluation and testing programs of Gujarat Agricultural University (GAU), Anand and Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PKV), Akola were also transferred to the Directorate w.e.f. 1st April 1990 as PKV, Akola centre was converted to centre of AICRP on Poultry Housing and GAU, Anand centre was mandated to work on alternative breeding strategies like reciprocal recurrent selection (Annual Report, 1991-92).

In the year 1990, objectives of the Directorate were framed as mentioned below

1. To coordinate and monitor research programmes carried out under AICRP on Poultry Breeding and other projects sanctioned by ICAR in different disciplines of Poultry.

2. To act as a repository of random bred control populations for egg and meat and elite layer and broiler germplasm resources available in the country/ to be imported from abroad and to undertake their genetic description and characterization with respect to economic, biochemical, immunologic and cytogenetic traits and resistance to diseases.

3. To plan and undertake the evaluation of commercial layers and broilers developed in the project *vis a vis* those available in the market from other hatchery sources.

4. To undertake further improvement, multiplication and supply of parent lines of crossbred layers and broilers developed and released from the project for their commercial exploitation.

5. To establish the norms of macro and micro nutrient requirements for various classes and age groups of poultry.

6. To develop least cost feed formulations and evaluate their efficacy by biological traits for sustaining high growth and production.

7. To undertake studies relating to alleviation of summer stress, litter materials, light requirements and other environmental factors to determine the biological efficiency management practices.
8. To undertake studies relating to surveillance and monitoring of poultry diseases to predict their onset and to undertake remedial measures for their prevention and control.

Subsequently in the year 1995-96, mandate of the Directorate was modified to six main points and for the first time emphasis was given for development of suitable germplasm for backyard/free range system of production.

1. To undertake basic, adaptive and applied research in genetics and breeding of poultry.
2. To coordinate and monitor research programmes carried out under All India Co-ordinated Research Projects.
3. To act as a repository of random bred control populations and elite poultry germplasm resources.
4. To undertake the evaluation of commercial layers and broilers developed in the project *vis a vis* those available in the private sector.
5. To develop germplasm suitable for backyard / free range poultry keeping for rural and tribal areas.
6. To undertake research in nutrition, management and health cover that are required to support the breeding research.

The research work under AICRP in Poultry Nutrition and Housing and Management was discontinued from April 1993 onwards. During the year 1995, the Research Advisory Committee in its first meeting has suggested several modifications in the existing mandates. Subsequently, mandate of the Directorate was revised effective from 1996 as mentioned below.

1. To undertake basic, adaptive and applied research in genetics and breeding of poultry.
2. To co-ordinate and monitor research programmes carried out under the All India Co-ordinated Research Projects.
3. To act as repository of random-bred control populations and elite poultry germplasm resources.
4. To undertake nutrition, management and health cover research that are required to support the breeding research. (Source: Perspective Plan 1996, 1997-2020)

Again in 1996-97, in accordance with the changing scenario of Indian Poultry Industry, the mandate of the Directorate were modified in to two main points

1. To co-ordinate and monitor ICAR sponsored research programs.

2. To undertake applied research on genetics and breeding of poultry and conservation of improved poultry germplasm with supportive research on poultry nutrition, disease control and management pertaining to the gene pool maintained and monitored by the PD on poultry. Special attention to be given to meet the needs of the rural/tribal areas and other under privileged sections.

Keeping in view the needs of poultry farming in the country and the challenges, the Directorate revised perspective plan 'Vision 2025' for a period of 20 years and accordingly the mandates were modified in 2006 (Annual Report, 2006-07) as mentioned below with the ***vision*** of "enhancing productivity of chicken for household nutritional security, income and employment generation" and with the ***mission*** of "developing and propagating improved varieties of chicken for sustainable production under intensive and extensive systems".

1. To co-ordinate and monitor ICAR-sponsored network research programmes

2. To undertake applied research on genetics and breeding, and conservation of improved chicken germplasm with supportive research on nutrition, disease control and management

3. To lay emphasis on development of chicken varieties to meet the needs of rural/tribal and other under-privileged sections of the society

The Project Directorate on Poultry was upgraded to Directorate of Poultry Research w.e.f 18th September, 2013. The Directorate became ISO9001:2008 certified Institute w.e.f 21st June 2014. Recently, the Directorate was conferred the prestigious Sardar Patel outstanding Institution award under small Institute category which was received by Dr. R. N. Chattejee, Director from the Honourable Prime Minister Shri. Narendra Modi on 29th July 2014.

The thrust area of the Directorate is Poultry Breeding with supportive research on poultry nutrition, health and management. This Institute is mandated to work only on chicken species of poultry. Presently, the Directorate is conserving and improving a total of 18 pure lines of chicken and conserving and characterizing three native breeds of chicken. The populations maintained are four lines of White Leghorn (IWH, IWI, IWK and layer control population); three broiler populations (PB-1, PB-2 and broiler control population); two gene lines (dwarf and naked neck); six lines developed for backyard poultry farming (PD-1, PD-2, PD3, PD-4, GML and rural control population) and three native chicken breeds (Aseel, Ghagus and Nicobari).

2. PD-1 line (Male line of Vanaraja)

Origin

PD-1 line was derived from Cornish breed of chicken. The Red Cornish strain (IC-3) was characterized by the golden red plumage, slow feathering and short shanks. This line was segregating for single and pea combs (Annual Report, 1991-92). IC-3 strain was maintained at Bangalore and Bhubaneswar centres under the component of Poultry for meat of AICRP on Poultry Breeding. Hatching eggs of Red Cornish strain maintained under AICRP on Poultry Breeding were procured from OUAT, Bhubaneswar and chicks were hatched at Project Directorate on Poultry, Hyderabad. Considering the better performance of synthetic female line for rural poultry in cross combination with red Cornish birds, a conscious decision was made to evolve Red Cornish strain (IC-3) into a separate male line for production of germplasm for backyard farming under the project entitled '*Development of a suitable male parent line for the backyard farming*' within the main program-IV of '*Development of germplasm for backyard/Free range farming for rural and tribal areas*' in the year 1998-99.

A pair of PD-1 birds

All surviving male and female birds were used as parents in the base generation and a pedigreed population was reproduced (Ayyagari, 2001). In initial generations, Red Cornish birds were screened for antibody titres to sheep red blood shells (SRBC) at six weeks of age and birds with extreme titre values were excluded. The titre values, egg production to 40 weeks of age in females and semen production in males and juvenile body weight and shank length in both sexes were taken in to consideration while selecting the breeders in Red Cornish birds (Ayyagari, 2001).

Selection for body weight at six weeks of age

The selection for higher body weight has started from S-0 generation onwards. In S-0 generation, Cornish birds were screened for SRBC titre at six weeks of age and were grouped into high, medium and low titre groups and mated within respective groups to produce the next (S-1) generation. Parents from S-1 generation were selected based on body weight at six weeks of age and SRBC titres and egg production up to 40 weeks of age. Parents were categorised as high, medium and low titre groups and bred within those groups to produce S-2 generation. In S-3 generation, the average intensity of selection for six weeks body weight was 0.44 while that for SRBC titre was 0.11. This method of selection was continued till S-3 generation.

Relationship between SRBC titres and adult growth and production traits

In S-4 generation, female birds of PD-1 line were categorised into high (9.81), medium (7.15) and low (2.75) titre groups and group wise performance in terms of growth and production traits were analysed. It was reported that birds of high antibody titres had low six weeks shank length, low juvenile and adult body weights, matured late, produced fewer eggs (40 weeks) with lesser egg weight (40 weeks) as compared to the medium and low antibody titre groups. This trend was not consistent in subsequent generations with respect to the juvenile growth traits and adult body weights. However, high titre groups consistently matured late with lesser 40 weeks egg production as seen in S-5 and S-6 generations.

Improvement for shank length at six weeks of age

In view of the importance of higher shank length of birds for quick running and thereby enabling to escape from predators, attempts were made to improve the male line for six weeks shank length. The heritability of six weeks shank length was high (0.45) on sire component basis and genetic correlation of shank length with four and six weeks body weight was positive and very high in magnitude while that between shank length and SRBC titre was negative in S-4 generation. Therefore, it was obvious that any attempt to improve shank length will invariably improve the juvenile body weights (4 or 6 weeks). From (S-8) SL-1 generation onwards, PD-1 birds were selected solely for higher shank length at six weeks of age. In S-8 (SL-1) generation, PD-1 birds were selected for higher shank length at six weeks. From this generation onwards, the selection criterion was changed to selection for higher shank length at six weeks of age alone instead of selection for higher body weight at six weeks of age as practiced in previous generations. From SL-2 generation onwards, the name of Vanaraja male line was coded as PD-1 line.

Effective population size and rate of inbreeding

The number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding over generations in PD-1 line are presented in Table 1. Average number of sires and dams used to regenerate the stock of this line over the generations were 47 and 188 respectively. Effective population size averaged over the generations was 147.4 while cumulative rate of inbreeding over the years was 0.0384. Rate of inbreeding (ΔF) has decreased from 0.005 to 0.003 and that level is being maintained during last four generations.

Table 1. Effective population size and rate of inbreeding in PD-1 line

Year	Generation	No. of Sires	No. of Dams	(Ne) Effective population size	(ΔF) Rate of inbreeding
1998-99	S0	33	132	105.6	0.0047
1999-00	S1	31	124	99.2	0.0050
2004-05	S6	50	150	150.0	0.0033
2005-06	S7	50	150	150.0	0.0033
2006-07	SL1	50	150	150.0	0.0033
2007-08	SL2	50	250	166.7	0.0030
2008-09	SL3	50	150	150.0	0.0033
2009-10	SL4	50	150	150.0	0.0033
2010-11	SL5	50	250	166.7	0.0030
2011-12	SL6	50	250	166.7	0.0030
2012-13	SL7	50	250	166.7	0.0030
2013-14	SL8	50	250	166.7	0.0030
Average		47	188	147.4	0.0345
Cumulative rate of inbreeding					0.0384

Fertility and hatchability

The data on fertility and hatchability is presented in Table 2. Fertility tend to (P<0.051) improve over the years (Y=1.152x+75.6). Similarly, hatchability both on fertile (Y=1.21x +79.2) and total egg set (Y=1.99x +59.2) has shown significant (P<0.004) improvement over the years. PD-1 line being a male parent line of Vanaraja, improvement in its fertility and hatchability traits is beneficial for production and supply of both pure line and commercial chicks. There was also concomitant increase in number of chicks hatched over the years for evaluation and improvement of primary trait.

Table 2. Fertility and hatchability traits of PD-1 line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
1999-00	S1	55.5	69.7	38.7	715
2000-01	S2	83.9	78.6	65.9	419
2001-02	S3	89.8	85.7	76.9	1295
2002-03	S4	81.4	91.7	74.6	1428
2003-04	S5	90.3	90.0	73.0	-
2004-05	S6	81.3	83.5	67.7	1267
2005-06	S7	88.9	89.3	79.2	1100
2006-07	SL1	-	-	-	1190
2007-08	SL2	82.2	90.5	74.2	1371
2008-09	SL3	87.9	91.6	80.4	1466
2009-10	SL4	80.4	95.3	76.6	1643
2010-11	SL5	88.7	94.1	83.5	3353
2011-12	SL6	88.6	94.3	83.5	3350
2012-13	SL7	91.0	94.9	86.2	3281
2013-14	SL8	89.5	87.2	78.0	2744
Average		84.2	88.3	74.2	-

FES- Fertile eggs set, TES-Total eggs set

Phenotypic response

The data on growth and production performance of PD-1 line over several generations is presented in Table 3.

1. **Body weights:** Body weights in this line were recorded at 4, 6, 20 and 40 weeks of age. Body weight recorded at four weeks of age did not follow any definite trend as regression of [$Y= (-2.56x+370.6)$] phenotypic response over generations was not significant ($P<0.529$). Similarly, body weight at six weeks of age ($Y=0.293x+657.8$) did not follow any trend ($P<0.950$). However, there was significant decline ($P<0.032$) in body weight recorded at 20 weeks of age [$Y= (-11.6x+2131)$] and 40 weeks ($P<0.01$) of age [$Y= (-25.7x+2976)$]. Body weight at 20 weeks of age declined from 2118 to 1925 g. while body weight recorded at 40 weeks of age declined from 3001 and 2671 g.

2. **Shank length at six weeks of age:** It is the primary trait of selection in PD-1 line. This line was subjected to selection for higher shank length since last 8 generations (SL-1). There was phenotypic improvement in shank length from 73.4 mm (S-4) to 76.3 mm (SL6 generation) although the trend ($Y=0.272x+72.25$) was not significant ($P<0.371$).

3. **SRBC tire at six weeks of age:** There was non-significant improvement in SRBC titre estimated at six weeks of age. Lowest titre recorded was 5.79 in SL-1 generation and highest titre recorded was 8.64 in SL3 generation.

4. **Age at sexual maturity:** There was no definite trend (Y=0.825x+173.3) in age at sexual maturity over last 14 generations (P<0.157). Lowest ASM recorded was 170.5 days (S-3 generation) and highest ASM recorded was 203.7 days (SL-7 generation).

5. **Egg weight:** No significant change in the egg weight recorded at 40 weeks of age was observed over 14 generations (Y=0.151x+52.96). Maximum egg weight recorded was 56.5 (S-7 generation) and minimum was 51.1 g (S-3 generation). Egg weight recorded at 32 weeks of age ranged between 48.8 and 52.6 g while egg weight at 28 weeks of age was in the range of 45.5 to 49 g over different generations.

6. **Egg number:** There was no significant change in egg number recorded up to 40 weeks of age (Y=0.456x+39.61). Highest 40 weeks egg production recoded in this line was 52.8 (SL-5 generation) and lowest was 34.6 eggs (S-3 generation).

Genetic Parameters

Heritability

Heritability estimates of various growth and production traits of PD-1 line determined on sire component of variance are presented in Table 4.

Body weight at four weeks of age: Heritability estimate of body weight at four weeks of age was highest (0.35) in S-3 generation but over the years it reduced to 0.11 (S-6 generation). This declining trend indicates that additive genetic variance of this trait has reduced over generations in this line.

Body weight at six weeks of age: Heritability estimate of body weight at six weeks of age was highest (0.40-0.54) during initial generations (S-3 and S-4). However, it reduced to lowest (0.11 and 0.13) level recorded during latest generations (S-6 and S-7). This particular trend indicates that additive genetic variance of this trait has reduced over generations. This decline in heritability of body weight both at four and six weeks of age might be due to the fact that this line underwent selection for higher six weeks body weight during initial generations and that might have resulted in reduction of variability of these traits.

Shank length at six weeks of age: Heritability estimate of shank length at six weeks of age followed similar trend as that of six weeks body weight. It was highest (0.45) in S-4 generation and lowest (0.05 and 0.06)) in latest (S-6 and S-7) generations. Declining trend indicates decrease in additive genetic variance due to selection being practiced for this trait.

SRBC titre at six weeks: Estimate of heritability of SRBC titre at six weeks of age was in low (0.13 in SL-2 generation) to moderate (0.24 in S-3 generation) range. The trend indicated that variability of this trait has declined over the generations (0.24 to 0.13).

Body weight at 20 and 40 weeks of age: Heritability estimates of body weights at 20 and 40 weeks of age were moderate to high (0.15 and 0.42) during initial generations but reduced to lowest (0.07 and 0.01) level in S-6 generation and again increased to 0.19 for 20 weeks body weight in S-7 generation. There was no clear cut trend in heritability estimates of these traits.

Age at sexual maturity (ASM): Heritability estimates of ASM was highest in initial generation (0.45 in SL-1), reduced to lowest (0.01 in S-5) and rose to moderate level (0.25) in S-7 generation. Reduction in heritability estimates of ASM might be explained from the fact that egg number up to 40 weeks of age and ASM are negatively correlated and any change in variability of egg production might also affect ASM.

Egg number to 40 weeks of age: Heritability estimate of egg number to 40 weeks of age during initial generation was moderate (0.24), then reduced to low (0.02) and again rose to 0.13 in S-7 generation. Overall there was reduction in heritability estimates of this trait.

Egg weight (28, 32 and 40 weeks): Heritability estimates of egg weights recorded at 40 weeks of age ranged from low (0.11) to high (0.40). It ranged from low to high (0.20 to 0.39) for 32 weeks egg weight while it was high (0.66) for egg weight recorded at 28 weeks of age.

Genetic correlation

It was interesting to note that the genetic correlation of egg production up to 40 weeks of age with body weight at 20 weeks of age determined on sire and dam component of variance was positive in direction and moderate (0.52) in magnitude while it was negative in direction and low to moderate in magnitude with other traits such as body weight at 40 weeks of age, egg weight at different ages and ASM. Similar trend was observed for phenotypic correlation in SL-1 generation.

It was observed that the genetic correlation between four and six weeks body weight with six weeks SRBC titre was moderate and positive while phenotypic correlation was low and negative as observed in S-3 generation. However, in S-4 generation, the genetic correlation between body weight and SRBC titre at six weeks of age was reported to be negative in direction and low in magnitude.

Table 3. Performance of PD-1 line with respect to various economic traits

Year	Generation	Body weight (g)*		SL at 6 wks (mm)*	SRBC at 6 wks ($\log_2$)*	ASM (d)	Body weight (g)		Egg weight (g)			EN to 40 wks
		4 wks	6 wks				20 wks	40 wks	28 wks	32 wks	40 wks	
1999-00	S-1	-	513	-	-	184.2	2108	3001	-	50.1	53.2	37.1
2000-01	S-2	-	723	-	-	182.2	2118	2995	-	49.5	53.2	40.5
2001-02	S-3	382	702	-	5.91	170.5	2022	2819	-	48.8	51.1	34.6
2002-03	S-4	348	697	73.4	7.63	173.0	2160	2818	-	48.9	53.4	45.4
2003-04	S-5	303	582	69.4	5.96	181.4	2143	3095	45.5	50.2	55.6	47.9
2004-05	S-6	403	740	75.0	6.25	172.5	2134	2734	49.8	52.6	54.3	43.2
2005-06	S-7	301	595	71.3	6.70	178.4	1881	2789	48.8	52.2	56.1	42.2
2006-07	SL-1	352	720	74.2	5.79	173.9	1977	2623	49.0	51.3	52.6	44.0
2007-08	SL-2	428	736	78.8	8.55	176.3	2085	2580	46.5	51.0	54.0	42.7
2008-09	SL-3	458	758	78.9	8.64	175.3	2012	2598	48.2	50.3	54.3	45.3
2009-10	SL-4	306	605	68.4	-	180.3	2037	2903	-	-	56.5	42.3
2010-11	SL-5	316	569	70.8	-	173.3	2036	2703	-	-	53.7	52.8
2011-12	SL-6	337	640	75.4	-	188.5	1986	2647	-	-	54.6	46.3
2012-13	SL-7	347	667	76.4	-	203.7	1925	2671	46.5	50.7	54.7	38.2
1013-14	SL-8	308	655	76.3	5.80	-	-	-	-	-	-	-

Note: *SL: Shank length, SRBC: Sheep Red Blood Cells, ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex,*

Table 4. Heritability estimates of growth and production traits of PD-1 line on sire component of variance

Generation	Body weight at				S.L. at 6 wks	SRBC titre at 6 wks	ASM	EN to 40 wks
	4 wks	6 wks	20 wks	40 wks				
S-3	0.38±0.12	0.40±0.13	-	-	-	0.24±0.09	-	-
S-4	0.33±0.14	0.54±0.19	-	-	0.45±0.16	0.19±0.06	-	-
S-5	-	-	-	-	-	-	-	-
S-6	0.22±0.11	0.43±0.14	-	-	0.39±0.11	0.21±0.10	-	-
S-7	0.24±0.12	0.19±0.13	-	-	0.31±0.13	0.16±0.09	-	-
SL-1	-	-	0.42±0.24	0.15±0.36	-	-	0.45±0.22	0.24±0.28
SL-2	0.18±0.07	0.17±0.08	-	-	0.19±0.07	0.13±0.05	-	-
SL-3	-	-	0.27±0.12	0.54±0.42	-	-	0.38±0.18	0.25±0.11
SL-4	0.24±0.09	0.25±0.08	0.16±0.20	0.04±0.21	0.18±0.07	-	0.26±0.22	0.02±0.21
SL-5	0.13±0.05	0.15±0.06	0.39±0.21	0.62±0.25	0.15±0.05	-	0.01±0.07	-
SL-6	0.11±0.04	0.11±0.04	0.07±0.14	0.01±0.14	0.05±0.05	-	0.04±0.14	0.03±0.14
SL-7	0.15±0.05	0.13±0.04	0.19±0.18	-	0.06±0.03	-	0.25±0.18	0.13±0.18

Note: *SL: Shank length, SRBC: Sheep Red Blood Cells, ASM: Age at sexual maturity, EN: Egg number, wks: weeks,*

3. PD-2 line (Female line of Vanaraja)

Origin

As the random bred coloured control broiler population was found to adapt well to the rural poultry rearing conditions, attempts were made to evolve this population into a separate line for backyard poultry farming based on its encouraging performance at field conditions. PD-2 line was evolved from the multicoloured broiler control population maintained at the Project Directorate on Poultry. Work to develop this line was initiated in the year 1997-98 from the random bred control broiler population. Hatching eggs of this line were supplied to commercial companies and to regional station of CARI, Bhubaneshwar for distribution in the rural/tribal areas. During the year 1997-98, a total of 1,17,458 hatching eggs were supplied. Furthermore, the performance of this line in cross combination with Cornish and with naked neck gene was tested in the same year. It was found that the body weight at six weeks of age improved by about 40 g in heterozygous naked neck condition and by about 100 g in cross combination with Cornish (male line). Subsequently, based on the feedback on performance of these birds during 4-5 years in rural and tribal areas of Andhra Pradesh, Orissa and Tamil Nadu states, a separate program (IV) titled '*Development of germplasm for backyard/free range farming for rural and tribal areas*' was launched in the year 1998-99. Under this program a subprogram titled '*Development of female parent line for the production of suitable germplasm for backyard farming*' was started in 1998-99. In this subprogram, then existing random bred coloured control broiler population (C-7 generation) was renamed as synthetic female line for rural poultry (SFR) in order to use this line as female line for development of a variety (Vanaraja) for backyard farming and this line was subsequently discontinued to be used as random bred control population for meat. During C-7 generation, the SFR line was evaluated for production traits up to 60 weeks of age. Egg production up to sixty weeks of age of SFR line was 111.1 eggs with an egg weight of 51.79 and 57.03 g respectively at 32 and 40 weeks of age.

A pair of birds of PD-2 line

From C-7 generation onwards, more emphasis was given for selection of birds based on egg number, egg weight and plumage pattern in females while weightage was given to antibody titre to sheep red blood cells (SRBC), shank length and plumage colour for selecting male birds. Rotational mating was followed to reproduce the first generation of SFR population. As the performance of this line in cross combination with the naked neck birds was found to be better in previous generation, separate sires with heterozygous naked neck (Nana) to mate with Nana females and normal phenotype (nana) sires to mate with normal (nana) females within the lines were maintained initially. From the year 1999-2000 onwards, the improvement of this line was continued under Program (I) titled Development of germplasm for backyard/free range farming for rural and tribal areas.

Improvement of PD-2 line

The C-8 (S-0) generation of PD-2 line was generated in the year 1999-2000 using parents from C-7 generation selected based on 40 weeks egg production, shank length and antibody titre against SRBCs. S-1 generation was reproduced using sires and dams selected based on egg production up to 40 weeks of age, shank length and SRBC titres at six weeks of age. During S-1 generation, PD-2 birds were selected based on higher body weight and SRBC titre at six weeks of age with selection intensity of 0.60 and 0.54 respectively. Subsequently, adult female birds (dams) were selected based on 40 weeks egg production using family index. Attention was also given to different plumage colour combinations while selecting dams for mating. During S-2 generation, selection for higher shank length at six weeks of age was introduced for the first time in the PD-2 line. Therefore, PD-2 birds were selected based on six weeks body weight, shank length and SRBC titres with selection intensity of 0.28, 0.46 and 0.32 respectively. Subsequently, dams were selected based on 40 weeks egg production record using family index selection method. In S-3 generation also, birds were selected based on body weight, shank length and SRBC titre at six weeks of age with selection intensity of 0.42, 0.53 and 0.53 respectively. Dams were subsequently selected based on 40 weeks egg production record using family index selection method. Birds in S-4 generation were also selected for higher body weight, shank length and SRBC titre at six weeks of age with selection intensity of 0.14, 0.26 and 0.43 respectively using selection method of independent culling level. In later phase, dams were selected based on 40 weeks egg production record using Osborne index. In S-5 generation also, PD-2 birds were subjected for selection for higher body weight, shank length and SRBC titres at six weeks with selection intensity of 0.10, 0.26 and 0.73 respectively using independent culling level selection.

Improvement for egg production up to 40 weeks of age

From S-6 generation onwards, the selection in PD-2 line was solely based on Osborne index for higher part period egg production up to 40 weeks of age. This criterion of selection was continued up to S-8 generation.

Improvement for egg production up to 52 weeks of age

From S-9 generation onwards, the selection criterion was changed from Osborne index for 40 weeks egg production to Osborne index for 52 weeks egg production. This method of selection is being practiced in this line till date.

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in PD-2 line is presented in Table 5. Average number of sires and dams used to regenerate the stock of this line over the generations were 53.2 and 243.1 respectively. Effective population size averaged over the years was 173.8 although it has reduced from 200 to 177. Average and cumulative rate of inbreeding over the years was 0.0029 and 0.0348 respectively and it was maintained under 0.003 since last three generations.

Table 5. Effective population size and rate of inbreeding in PD-2 line

Year	Generation	No. of Sires	No. of Dams	(Ne) Effective population size	(ΔF) Rate of inbreeding
2000-01	S-1	60	300	200.0	0.0025
2001-02	S-2	60	300	200.0	0.0025
2002-03	S-3	50	200	160.0	0.0031
2003-04	S-4	50	250	166.7	0.0030
2005-06	S-5	60	290	198.9	0.0025
2006-07	S-6	50	250	166.7	0.0030
2007-08	S-7	50	250	166.7	0.0030
2008-09	S-8	50	250	166.7	0.0030
2010-11	S-9	50	150	150.0	0.0033
2011-12	S-10	50	250	166.7	0.0030
2012-13	S-11	50	250	166.7	0.0030
2013-14	S-12	59	177	177.0	0.0028
Average		53.2	243.1	173.8	0.0029
Cumulative rate of inbreeding					0.0348

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in each generation are presented in Table 6. There was no significant change in fertility over generations (Y= (-1.05x +87.8)]. Similarly, there was no significant change in hatchability both on fertile [Y= (0.09x +87.2)] and total egg set [Y= (-0.73x+74.49)]. Fertility and hatchability are fitness traits and the trend of no significant change in negative direction is desirable as PD-2 line being the female parent line of Vanaraja, maintaining better fertility and hatchability in this line will help in the production of commercial chicks in large numbers.

Table 6. Fertility and hatchability traits of PD-2 line

Year	Generation	Fertility (%)	Hatchability (%)		No. of Chicks Hatched
			FES	TES	
2000-01	S-1	81.2	83.6	67.9	-
2001-02	S-2	83.6	88.4	69.7	3080
2002-03	S-3	92.1	87.4	73.8	2968
2003-04	S-4	80.5	83.7	67.4	3378
2005-06	S-5	87.0	91.0	79.0	-
2006-07	S-6	87.8	91.7	80.5	3176
2007-08	S-7	85.8	87.6	75.2	2380
2008-09	S-8	79.1	92.5	73.1	2008
2010-11	S-9	66.1	86.7	57.3	1906
2011-12	S-10	70.7	88.7	62.3	2466
2012-13	S-11	73.7	88.2	60.0	3145
2013-14	S-12	84.3	83.9	70.8	2032
Average		81.0	87.8	69.7	-

FES- Fertile eggs set, TES-Total eggs set

Phenotypic response

Data on the performance of PD-2 line with respect to various growth and production traits over generations are presented in Table 7.

1. **Body weights:** Body weights were recorded at 4, 6, 20 and 40 weeks of age over generations. Body weight at 4 weeks of age did not follow definite trend as regression of phenotypic response over generations [Y= (-9.56x+401.9)] was not significant (P<0.123) although it declined in latest generations. Body weight at 6 weeks of age (Y=-11.4x+735.9) declined over generations but it was not significant (P<0.08). There was no significant change in in body weight at 20 weeks of age [Y= (-3.78x+2058.9)] as well. However, body weight at 40 weeks of age [Y= (-33.02x+2876)] has declined significantly (P<0.04) over generations.

2. **Shank length at six weeks of age:** Shank length at six weeks of age over generations has declined significantly (P<0.006) from 88.9 (S-1 generation) to 66.2 mm (S-9 generation) as revealed by regression [Y= (-1.575x+83.69)] of phenotypic response on number of generations.

3. **SRBC tire at six weeks of age:** There was no significant change in SRBC titre estimated at six weeks of age (Y=0.161x+6.33) although highest SRBC tire recorded was 9.56 (S-8 generation) and lowest was 5.22 (S-4 generation).

4. **Age at sexual maturity (ASM):** ASM has declined over last 13 generations [(Y= (-1.26X+173.60)] from 177 (S-2 generation) to 153.5 d (S-9 generation). This decline in ASM could be attributed to the selection for early part period egg production (40 or 52 weeks) practiced in this line.

5. **Egg weight:** There was significant ($P<0.001$) reduction in egg weight recorded at 40 weeks of age over 13 generations [(Y= (-0.41X+57.4]. Highest average egg weight recorded was 58.2 g (S-2 generation) while lowest was 51.6 g (S-11 generation). Similarly, there was significant ($P<0.002$) decline in egg weight recorded at 32 weeks of age over 13 generations [(Y= (-0.39X+54.49]. Highest average egg weight recorded was 55.0 g (S-2 generation) while lowest was 48.9 g (S-9 generation). Egg weight at 28 weeks of age [(Y= (-0.49x+50.64] also declined significantly ($P<0.046$) from 51.3 g (S-1 generation) to 46.5 g in (S-11 generation).

6. **Egg number:** Egg number up to 40 weeks of age increased significantly ($P<0.0001$) over last 12 generations [(Y= (2.201x+52.7)]. Lowest egg number recorded was 47.8 (S-0 generation) and highest was 81.8 eggs (S-8 generation). Egg number up to 52 weeks of age also improved as it has increased from 108 (S-9 generation) to 115 eggs recorded (S-10 generation). This line produced 202.3 eggs up to 72 weeks of age with average egg weight of 56.45 g at 72 weeks of age in S-10 generation.

Genetic Parameters

Heritability

Heritability estimates of various traits determined on sire component of variance over several generations in PD-2 line are presented Table 8.

Growth traits: Heritability estimates of body weights at 4 and 6 weeks of age were high (0.54 and 0.39) in initial generations but reduced to lower level in subsequent generations (S-6) but again increased to moderate (0.17 and 0.34) level in latest generation (S-9). Similarly, for shank length heritability estimates were high during initial generation and ranged between low to moderate in subsequent generations. This decline in estimates of heritability was mostly due to selection practiced for higher body weight and shank length at six weeks of age. Heritability estimate of body weight at 20 weeks of age ranged between low to moderate while that of body weight at 40 weeks of age ranged between moderate to high over generations.

Production traits: Heritability estimates of egg production up to 40 weeks of age were in moderate level over several generations (0.18 to 0.26) and thus there was an improvement in egg production up to 40 weeks of age, being the selection criterion in PD-2 line during 12 generations. However, the heritability estimates of egg production up to 52 weeks of age was low **(**0.12±0.11) and that of egg weight at 52 weeks of age was moderate (0.28±0.11) as determined on sire component of variance during S-9 generation. The heritability of ASM was high (0.42) during initial generations but declined to lower magnitude (0.12) in later generations (S-9). Heritability estimates recorded for egg weights at 28, 32 and 40 weeks of age were mostly in higher range (0.49 - 0.58 as recorded in S-11 generation) suggesting that these traits can be improved if selected for higher egg weights.

Genetic correlation

In S-5 generation, interestingly the egg production up to 40 weeks of age and body weight at 20 weeks of age were positively correlated (0.49) on genetic scale while genetic correlation of egg production up to 40 weeks of age with ASM (-0.75), body weight at 40 weeks (-0.56) and egg weight at 40 weeks (-0.52) was negative in direction and moderate to high in magnitude as determined on sire and dam components of variance. In S-7 generation, genetic correlations among juvenile growth traits such as body weight at four and six weeks of age and shank length at six weeks of age were positive and high in magnitude while genetic correlation of juvenile growth traits with SRBC titres at six weeks was negative and moderate in magnitude (-0.28 to -0.43).

Table 7. Performance of PD-2 line with respect to various economic traits

Year	Generation	Body weight (g)*		SL at 6 wks (mm)*	SRBC titre at 6 wks (log_2)	ASM (d)	Body weight (g)		Egg weight (g)			EN to 40 wks	EN to 52 wks
		4 wks	6 wks				20 wks	40 wks	28 wks	32 wks	40 wks		
1998-99	C-7	-	706	-	-	170.5	2030	3190	-	51.8	57.0	-	-
1999-00	C-8/S-0	-	658	-	-	174.5	1856	-	-	53.9	56.3	47.8	-
2000-01	S-1	376	770	88.9	7.78	172.8	2027	2580	51.3	53.3	54.8	64.8	-
2001-02	S-2	340	657	74.9	5.97	177.0	2084	2866	-	55.0	58.2	62.2	-
2002-03	S-3	344	614	75.2	8.43	166.0	2092	2808	-	53.5	56.6	61.5	-
2003-04	S-4	434	669	76.6	5.22	153.8	2306	2543	-	52.3	53.5	61.1	-
2005-06	S-5	382	727	77.1	5.78	170.4	2141	2512	49.4	51.2	53.7	63.5	-
2006-07	S-6	355	727	76.3	6.45	167.2	2011	2474	49.6	53.0	54.3	67.7	-
2007-08	S-7	318	638	70.7	7.26	148.9	1907	2623	46.9	50.2	52.1	65.4	-
2008-09	S-8	402	693	73.4	9.56	155.8	1968	2595	46.7	49.7	53.1	81.8	-
2010-11	S-9	310	618	71.5	-	153.5	1974	2572	48.5	49.1	53.6	75.9	108.5
2011-12	S-10	-	-	-	-	165.9	2087	2553	48.6	50.8	53.5	75.8	115.1
2012-13	S-11	234	463	65.8	-	166.4	1921	2619	46.5	48.9	51.6	76.6	116.1
2013-14	S-12	249	488	66.2	-	-	-	-	-	-	-	-	-

Note: *SL: Shank length, SRBC: Sheep Red Blood Cells, ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Combined sex*

Table 8. Heritability estimates of various economic traits of PD-2 line estimated on sire component basis

Year	Generation	Body weight (g)		S.L. at 6 wks	SRBC titre at 6 wks	Body weight (g)		ASM	Egg weight (g)			EN to 40 wks
		4 wks	6 wks			20 wks	40 wks		28 wks	32 wks	40 wks	
1999-00	C-8/S-0		0.21±0.14		-	0.21±0.11	-	0.43±0.17	-	0.02±0.14	0.09±0.11	-
2000-01	S-1	0.54±0.11	-	0.85±0.13	-	-	-	-	-	-	-	-
2002-03	S-3	0.17±0.07	0.39±0.12	0.29±0.09	0.16±0.06	-	-	-	-	-	-	-
2003-04	S-4	0.28±0.09	0.19±0.07	0.22±0.08	0.02±0.05	0.34±0.18	0.06±0.12	0.42±0.21	-	0.31±0.16	0.50±0.27	0.21±0.21
2005-06	S-5	0.26±0.06	0.18±0.06	0.02±0.01	0.04±0.03	0.26±0.13	0.63±0.21	0.30±0.15	0.46±0.17	-	0.16±0.13	0.26±0.14
2006-07	S-6	0.06±0.03	0.13±0.05	0.09±0.04	0.49±0.21	0.02±0.06	0.20±0.12	0.02±0.10	0.22±0.11	0.40±0.16	0.31±0.10	0.21±0.77
2007-08	S-7	0.15±0.05	0.23±0.07	0.15±0.05	0.09±0.03	0.01±0.12	0.32±0.16	0.13±0.15	0.43±0.17	0.52±0.18	0.65±0.21	0.22±0.13
2010-11	S-9	0.17±0.06	0.34±0.09	0.14±0.05	-	0.13±0.05	0.35±0.16	0.12±0.09	0.13±0.10	0.14±0.14	0.13±0.11	0.18±0.12
2012-13	S-11	-	-	-	-	0.32±0.18	0.45±0.21	-	0.59±0.20	0.58±0.23	0.49±0.24	0.20±0.08

***Note:** SL: Shank length, SRBC: Sheep Red Blood Cells, ASM: Age at sexual maturity, EN: Egg number, wks: weeks*

4. PD-3 line (Female line of Gramapriya and Srinidhi)

Origin

PD-3 line was evolved from Dahlem Red breed, which is an exotic coloured breed originated from Germany. The work on development of PD-3 line as female line for production of egg type rural poultry (Gramapriya®) was started in the year 1998-99 by procuring exotic coloured layer population (Dahlem Red) in small number (PDP Annual Report 1998-99) from Central Avian Research Institute (CARI), Izatnagar. Dahlem Red population was expanded from a small number of chicks. Hatching eggs of this line were made available to supply for propagating in rural/tribal areas through CARI regional centre, Bhubaneshwar, Orissa. Only 180 females belonging to two hatches were available for recording the production traits in second generation (1999-2000). The average egg production recorded up to 40 weeks of age was 59.02 during this generation. Again considerable number of hatching eggs were sent to CARI regional centre, Bhubaneshwar and KAU, Mannuthy for propagation of this germplasm in the rural/tribal areas.

A pair of PD-3 line birds

Pedigreed population of Dahlem Red breed (S-0 generation) was produced for the first time in 2000-01 using 32 sires mated to 128 dams in a 1:4 ratio. In S-0 generation, PD-3 birds were selected based on 40 weeks egg mass. A total of 30 sires and 120 dams were used to regenerate S-1 generation. A random bred control population from S-0 generation of PD-3 line was generated using pair mating method to assess the genetic improvement of PD-3 line in subsequent generations. After recording the performance in S-6 generation, the random mating (Using pooled semen) in PD-3 line was carried out and thus G-0 generation was produced in 2010-11.

Selection criterion

Birds in PD-3 line are being selected for higher egg mass at 40 weeks of age using Osborne index and 50 sires and 200 dams so selected were mated in 1:4 ratio to reproduce subsequent generation.

Effective population size and rate of inbreeding

The data on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in PD-3 line are presented in Table 9. Average number of sires and dams used to regenerate the stock of this line over several generations was 42.6 and 174.2 respectively. Effective population size averaged over the generations was 136.9 but it has increased from 102.4 (S-0 generation) to 160 (G-3 generation). Average and cumulative rate of inbreeding over generations was 0.0038 and 0.0414 respectively but it was maintained under 0.0032 since last three generations.

Table 9. Effective population size and rate of inbreeding in PD-3 line

Year	Generation	No. of Sires	No. of Dams	Effective populationsize (Ne)	Rate of inbreeding (ΔF)
2000-01	S-0	32	128	102.4	0.0049
2002-03	S-1	30	120	96.0	0.0052
2003-04	S-2	50	200	160.0	0.0031
2004-05	S-3	40	200	133.3	0.0038
2005-06	S-4	40	160	128.0	0.0039
2007-08	S-5	40	160	128.0	0.0039
2008-09	S-6	40	160	128.0	0.0039
2010-11	G-0	48	192	153.6	0.0033
2011-12	G-1	49	196	156.8	0.0032
2012-13	G-2	50	200	160.0	0.0031
2013-14	G-3	50	200	160.0	0.0031
Average		42.6	174.2	136.9	0.0038
Cumulative rate of inbreeding					0.0414

Fertility and hatchability

The data on fertility, hatchability and number of chicks hatched are presented in Table 10. There was decline in fertility from 81.2% (S-0 generation) to 73.2% (G-3 generation) but it was not significant (P<0.130) over the generations [(Y= (-1.65x +82.1)]. However, hatchability on FES increased from 65.3% (S-0 generation) to 87.7% (G-3 generation) although the trend [Y= (0.91x+72.6)] was not significant (P<0.223). Similarly, there was no significant (P<0.488) change in hatchability on TES [Y= (-1.034x+66.10)] as it increased marginally from 62.4% (S-1 generation) to 63.2% (G-3 generation). Improvement in hatchability of PD-3 line is desirable as it is the female of Gramapriya cross and that will help in producing more number of commercial chicks. However, declining fertility in this line needs to be addressed.

Table 10. Fertility and hatchability traits of PD-3 line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2000-01	S-0	81.2	65.3	-	-
2002-03	S-1	90.5	76.3	62.4	1325
2003-04	S-2	76.8	83.2	63.9	2491
2004-05	S-3	70.0	88.0	61.0	-
2005-06	S-4	69.6	63.4	60.4	-
2007-08	S-5	70.0	85.9	60.4	-
2008-09	S-6	80.0	71.9	89.8	1371
2010-11	G-0	44.7	79.9	35.7	1503
2011-12	G-1	53.0	77.4	41.0	1052
2012-13	G-2	76.8	84.9	62.2	2283
2013-14	G-3	73.2	87.7	63.2	2357
Average		71.4	78.5	60.0	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

Data on the performance of PD-3 line with respect to growth and production traits over generations is presented in Table 11.

1. **Body weights:** Body weights were recorded at 20 and 40 weeks of age over generations in PD-3 line. There was no significant change in body weight recorded at 20 weeks of age [Y= (-12.42x+1285.8)] but it declined from 1425 (S-0 generation) to 1339 g (G-3 generation). Similarly, body weight at 40 weeks of age [Y= (-17.8x+1785.4)] declined non-significantly over generations.
2. **Age at sexual maturity (ASM):** There was no significant change in ASM recorded over last 11 generations [(Y= (-0.004x+172.8)] although there was considerable variation from generation to generation with highest ASM of 190.8 d and lowest of 163.3 d. However, it slightly reduced from 169.4 (S-0 generation) to 165.9 d (G-3 generation) with average of 172.6 d.
3. **Egg weights:** There was significant ($P<0.015$) reduction in egg weight recorded at 28 weeks of age over 11 generations [(Y= (-0.308x+51.7)] from 53.0 (S-2 generation) to 49.6 g (G-3 generation). Similarly, there was significant ($P<0.002$) reduction in egg weight recorded at 32 weeks of age over 13 generations [(Y= (-0.44x+54.57)]. It has reduced from 54.7 (S-1 generation) to 50.2 g (G-3 generation). Interestingly, there was no significant ($P<0.119$) change in egg weight recorded at 40 weeks of age [(Y= (-1.60x+55.7)] over generations. This finding might be due to the fact that this line is being selected for higher egg mass at 40 weeks of age and hence there was no reduction in egg weight recorded at 40 weeks of age.

4. **Egg mass at 40 weeks of age:** This is the primary trait of selection in PD-3 line and birds in this line are being selected for higher egg mass at 40 weeks of age. There was no significant change in egg mass over generations [(Y= (-95.3x+4407.1)] although it declined from 4754 (S-1 generation) to 3960 g (G-3 generation) with average egg mass of 3883 g.

5. **Egg number to 40 weeks of age:** There was no significant change in egg number to 40 weeks of age over last 12 generations [(Y= (-1.35x+78.1)]. Highest egg number recorded was 86.7 eggs (S-1 generation) and lowest egg number recorded was 61.9 (S-5 generation) and from there it increased to 72.7 during latest (G-3) generation.

Genetic Parameters

Heritability

Heritability estimates determined on sire component of variance of various traits recorded over generations in PD-3 line are presented in Table 12.

Body weights at 20 and 40 weeks of age: Heritability estimates of body weight recorded at 20 weeks of age were mostly in the range of moderate to high except in one generation (0.14) and not much change has occurred over generations. However, there was no consistency in the heritability estimates of body weight recorded at 40 weeks of age as they were in the range of very low (0.03) to very high (0.75) in different generations.

Production traits: There was little change in heritability estimates of ASM as they were mostly in the range of moderate to high (0.30 to 0.37) except for few generations in which they were in lower range (0.01 to 0.14). Similarly, there was no change in estimates of heritability for egg production recorded up to 40 weeks of age as they were mostly in moderate (0.18) to high (0.35) range over generations except in one generation where it was in lower range (0.14). Heritability estimates recorded for egg weight at 28 weeks of age were also in moderate to high range (0.18 to 0.35) except in one generation (0.13) while those of egg weight recorded at 32 weeks of age were in higher range (0.35 to 0.60) except in two generations (0.02 to 0.11). However, heritability estimates of egg weight recorded at 40 weeks of age were mostly in the range of moderate to high (0.29 to 0.69). These findings suggest that still there is a moderate to high additive genetic variation in this line for these traits and hence there is a scope for improvement of egg weights. Heritability estimates of egg mass at 40 weeks of age (primary trait of selection) were in the range of moderate to high (0.15 to 0.35) and not much change has occurred over generations. This implies that this line could still be improved for this particular trait as well.

Genetic correlation

The genetic correlation of egg mass at 40 weeks of age with egg number to 40 weeks of age (0.96) and body weight at 20 weeks of age (0.85) was positive in direction and high in magnitude and that with egg weight at 40 weeks of age (0.10) was positive and low in magnitude. The genetic correlation of 40 weeks egg mass with age at sexual maturity was negative in direction and high in magnitude (-0.99) while that with egg weight at 28 weeks (-0.24) and 32 weeks (-0.12) of age were low and negative in direction as estimated based on sire component of variance in S-1 generation. Similarly, the genetic correlation in S-2 generation between egg mass at 40 weeks and egg number to 40 weeks of age (0.97) was high and positive while that with egg weight at 28 (0.54) and 32 (0.42) weeks of age and body weight at 20 weeks of age (0.55) were moderate and positive in direction and that with age at sexual maturity (-0.67) was high and negative in direction. In S-3 generation, the genetic correlation of 40 weeks egg mass with 40 weeks egg production (0.88), 40 weeks body weight (0.83) and 28 weeks egg weight (0.68) were high and positive and that with 32 weeks (0.28) and 40 weeks (0.25) egg weights were positive and moderate in magnitude while that with age at sexual maturity (-0.42), body weight at 20 weeks of age (-0.22) were respectively moderate and low in magnitude and negative in direction as estimated on sire component of variance. Results suggest that genetic correlations of egg mass (primary trait) with other traits were by and large consistent over three generations and were on expected line (except with body weight at 20 weeks and egg weight at 28 and 32 weeks)

Table 11. Performance of PD-3 line with respect to various economic traits

Year	Generation	Body weight (g)		ASM (d)	Egg weight (g)			EN to 40 wks	Egg mass to 40 wks (g)
		20 wks	40 wks		28 wks	32 wks	40 wks		
2000-01	S-0	1425	1789	169.4	51.2	-	-	-	-
2002-03	S-1	1379	1732	167.2	53.0	54.7	54.9	86.7	4754
2003-04	S-2	1053	1722	183.2	48.9	52.9	55.6	65.5	3640
2004-05	S-3	1176	1855	178.0	51.3	53.9	56.1	79.6	4451
2005-06	S-4	1221	1744	175.7	50.2	53.7	56.3	75.1	4451
2007-08	S-5	1156	1565	164.3	49.3	51.3	54.5	61.9	3375
2008-09	S-6	1282	1596	163.3	49.3	50.8	54.1	75.3	4013
2010-11	G-0	1092	1501	168.2	48.8	51.2	53.3	64.5	3450
2011-12	G-1	958	1597	190.8	48.9	52.2	54.4	51.6	2812
2012-13	G-2	1243	1663	172.8	48.0	50.7	54.9	74.3	3923
2013-14	G-3	1339	1698	165.9	49.6	50.2	54.5	72.7	3960

Note: *ASM: Age at sexual maturity, EN: Egg number, wks: weeks*

Table 12. Heritability estimates of various economic traits of PD-3 line estimated on sire component of variance

Generation	Body wt. at 20 wks	Body wt. at 40 wks	ASM	Egg wt. at 28 wks	Egg wt. at 32 wks	Egg wt. at 40 wks	EN to 40 wks	Egg mass at 40 wks
S-1	0.38±0.18	0.11±0.11	0.37±0.14	0.30±0.18	0.41±0.19	0.34±0.17	0.19±0.11	0.15±0.10
S-2	0.23±0.11	0.41±0.15	0.01±0.06	0.21±0.13	0.02±0.12	0.15±0.13	0.18±0.10	0.18±0.11
S-3	0.14±0.13	0.03±0.11	0.11±0.13	0.33±0.17	0.35±0.12	0.38±0.18	0.14±0.13	0.16±0.13
S-4	0.48±0.20	0.75±0.26	0.27±0.20	0.35±0.14	0.60±0.23	0.51±0.23	0.30±0.16	0.27±0.16
S-5	-	-	0.36±0.16	-	-	0.34±0.17	0.25±0.14	-
G-1	0.68±0.21	0.51±0.23	0.14±0.16	0.13±0.10	0.11±0.11	0.69±0.26	0.35±0.23	0.35±0.23
G-2	0.21±0.17	-	0.30±0.13	0.26±0.09	0.35±0.20	0.29±0.12	0.20±0.12	0.22±0.12
G-3	-	-	0.30±0.13	0.18±0.26	0.35±0.20	0.29±0.12	0.18±0.12	0.22±0.09

Note: *ASM: Age at sexual maturity, EN: Egg number, wks: weeks*

5. Gramapriya Male Line (GML)

Origin

Since there was no separate male parent line for egg type Gramapriya variety, it was envisaged to develop a separate male line for this Germplasm. The base generation (SL-0) GML was produced by random mating of the existing PD-2 line using pooled semen.

Selection criterion

Selection for higher shank length at six weeks of age using mass selection is the method of selection being practiced in this line.

A pair of GML birds

Effective population size and rate of inbreeding

The data on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in this line are presented in Table 13. Effective population size averaged over the years is 162.50. Average and cumulative rate of inbreeding over generations was 0.0031 and 0.0123.

Table 13. Effective population size and rate of inbreeding in Gramapriya male line

Year	Generation	No. of Sires	No. of Dams	(Ne) Effective population size	(ΔF) Rate of inbreeding
2010-11	SL-1	50	200	150.00	0.0033
2011-12	SL-2	50	150	166.67	0.0030
2012-13	SL-3	50	250	166.67	0.0030
2013-14	SL-4	50	250	166.67	0.0030
Average				162.50	0.0031
Cumulative rate of inbreeding					0.0123

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in GML are presented in Table 14. Fertility in this line ranged from 86 to 89.6% while hatchability ranged from 88.02 to 93.95% on FES and 78.8 to 83.2% on TES basis.

Table 14. Fertility and hatchability traits of Gramapriya male line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2009-10	SL-0	-	-	-	2568
2010-11	SL-1	87.65	91.12	80.0	2812
2011-12	SL-2	88.61	93.95	83.25	2997
2012-13	SL-3	86.00	93.00	80.00	3703
2013-14	SL-4	89.56	88.02	78.83	3014
Average		87.95	91.52	80.52	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

Data on the performance of GML with respect to various economic traits over generations is presented in Table 15.

Growth traits: There was not much change in growth traits recorded over four generations except there was increase in body weight recorded at 40 weeks of age.

Production traits: Age at sexual maturity declined from 179.7 to 159.8 days while egg production up to 40 weeks of age has remarkably increased from 66.74 to 82.49 eggs in a short period of time with no change in egg weights recorded at various intervals up to 40 weeks of age.

Table 15. Performance of Gramapriya male line with respect to various economic traits

Year	Generation	6 wks S.L. (mm)*	Body weight (g)				ASM (d)	Egg weight (g)				EN to 40 wks
			6 wks*	20 wks	30 wks	40 wks		28 wks	32 wks	36 wks	40 wks	
2010-11	SL-0	73.24	576	1728	2380	2384	179.7	48.1	52.0	52.79	53.39	66.74
2011-12	SL-1	68.89	504	1998	2185	2443	156.9	46.9	-	-	51.86	69.39
2012-13	SL-2	69.56	489	2076	2470	2584	153.7	47.6	-	52.34	54.93	80.76
2013-14	SL-3	71.20	577	1896	2400	2603	159.8	46.7	50.56	52.93	54.93	82.49

Note: ** Pooled sex, S.L.: Shank length, ASM: Age at sexual maturity, EN: Egg number, wks: weeks*

6. PB-1 line (Male line of Krishibro- Coloured Broiler)

Origin of synthetic meat type lines

The synthetic meat type lines such as PB-1 and PB-2 were developed at Punjab Agricultural University, Ludhiana under AICRP on Poultry Breeding (Poultry for meat) as coloured synthetic male and female lines respectively to produce coloured commercial broilers. Towards the fag end of 1988, these two broiler lines (PB-1 and PB-2: Parent lines of IBL-80) were procured by the Project Directorate on Poultry, Hyderabad from PAU, Ludhiana and maintained them under nucleus stock production unit that was established on 17th March 1988 to supply fertile eggs or chicks of these germplasm to the government and private agencies.

PB-1 line (Male line of Krishibro)

The PB-1 line was developed from *inter-se* mating of commercial stocks (AICRP Annual Report, 1991-92). The work on selection of PB-1 line was started in the year 1977-78 using 50 sires and 150 dams. Initially, PB-1 line was selected for increased growth rate and subsequently for higher growth as well as higher egg production up to 40 weeks of age (AICRP Annual Report, 1991-92).

A pair of PB-1 line birds

Selection criterion at PAU, Ludhiana

The mass selection for higher body weight at eight weeks of age coupled with culling level selection for conformation traits was followed in this line up to 1985-86. Criterion of selection changed to mass selection for higher body weight and conformation traits at six weeks of age since 1986-87.

Selection criterion at DPR, Hyderabad

Selection criterion followed at PDP, Hyderabad for PB-1 line was mass selection for body weight at six weeks of age. However, from S-10 generation onwards, birds of PB-1 line are being selected for higher body weights at 5 weeks of age. PB-1 line has undergone two generations of random mating during 1999 and 2000 (Annual Report, 2001-02). In the year 2002-2003, the first pedigreed mating was carried out using 55 males and 220 females selected on the basis of 5 week body weight. In the year 2003-04, the G-2 generation was produced using 50 sires and 200 dams selected based on 5 weeks body weight. In the year 2004-05, the G-3 generation was generated using 60 sires and 300 dams selected based on 5 weeks body weight. Average selection differential over 9 generations was 144.8 g with average intensity of selection of 1.093 in 10 generations for body weight at 5 weeks of age.

Two populations of PB-1 line i.e., colour and white populations were maintained since 2006-07 to 2008-09. From the year 2009 onwards, regeneration of white population of PB-1 line was discontinued.

Effective population size and rate of inbreeding

The data on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in PB-1 line are presented in Table 16. Average number of sires and dams used to reproduce the stock of this line over the generations was 55.9 and 185.8 respectively. Effective population size averaged over the years was 185.8 but it has increased from 183.2 (S-7 generation) to 226.2 (S-24 generation). Cumulative rate of inbreeding was 0.0336 and average rate of inbreeding was 0.0028 over generations.

Table 16. Effective population size and rate of inbreeding of PB-1 line

Generation	Year	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
S-12/G1	2002-03	55	275	183.3	0.0027
S-14/G2	2003-04	50	200	160.0	0.0031
S-15/G3	2004-05	60	300	200.0	0.0025
S-16	2005-06	80	400	266.7	0.0019
S-17	2006-07	40	198	133.1	0.0038
S-18	2007-08	43	215	143.3	0.0035
S-19	2008-09	50	250	166.7	0.0030
S-20	2009-10	45	225	150.0	0.0033
S-21	2010-11	50	250	166.7	0.0030
S-22	2011-12	60	300	200.0	0.0025
S-23	2012-13	70	350	233.3	0.0021
S-24	2013-14	68	336	226.2	0.0022
Average		55.9	274.9	185.8	0.0028
Cumulative rate of inbreeding					0.0336

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in PB-1 line are presented in Table 17. There was significant (P<0.04) improvement in fertility [(Y= (0.72x +73.3)] from 70.3 (S-7 generation) to 86.8% (S-24 generation) with average of 79.7%. Similarly, there was significant (P<0.0001) increase in hatchability on FES [Y= (0.87x+79.04)] from 80.9 (S-7 generation) to 92.5% (S-17 generation) and to 91.8% in latest (S-24) generation. There was also significant (P<0.001) improvement in hatchability on total egg set (Y= (1.34x+57.33) from 57.2 (S-7 generation) to 79.6% (S-24 generation). Average hatchability on FES and TES basis was 92.5 and 77.8% respectively. Improvement in fertility and hatchability traits observed in this line is in desirable direction as it helps in producing more number of commercial chicks.

Table 17. Fertility and hatchability traits of PB-1 line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
97-98	S-7	70.3	80.9	57.2	1716
98-99	S-8	86.0	81.1	69.7	8115
99-2000	S-9	82.4	83.7	68.9	5454
2000-01	S-10	81.9	76.7	62.8	9663
2001-02	3rd generation	71.0	82.0	57.8	2559
2002-03	1st pedigree	78.0	87.0	67.0	4194
2003-04	G-2	66.9	79.7	53.3	2367
2004-05	G-3/S-15	72.7	86.4	62.8	2991
2005-06	S-16	73.1	87.4	63.9	4771
2006-07	S-17	84.2	92.5	77.8	2757
2007-08	S-18	77.1	90.0	69.4	3458
2008-09	S-19	73.6	91.3	67.2	2325
2009-10	S-20	87.2	92.4	80.5	4617
2010-11	S-21	90.5	92.2	83.4	4903
2011-12	S-22	86.4	90.6	78.3	5290
2012-13	S-23	87.7	90.6	79.4	5056
2013-14	S-24	86.8	91.8	79.6	5008
Average		79.7	85.6	71.4	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

Data on the performance of PB-1 line with respect to various growth and production traits over generations are presented in Table 18.

1. **Body weights:** Body weights were recorded at 5, 20 and 40 weeks of age over generations in PB-1 line. There was no significant change in body weight at 5 weeks of age [Y= (-1.37x+934.8)] although it improved from 737 (S-7 generation) to 996 g (S-23 generation). There was non-significant decline in body weight at

20 weeks of age [Y= (-19.7x+2788)] from 2763 (S-7 generation) to 2592 g (S-23 generation). However, body weight at 40 weeks of age [Y= (-23.4x+3692.7)] has significantly (P<0.04) declined from 3704 (S-7 generation) to 3357 g (S-23 generation).

2. **Shank length and breast angle:** There was no significant change in shank length [Y= (-0.78x+83.54)] and breast angle [Y= (-1.06x+96.6)] recorded at five weeks of age over generations.

3. **Age at sexual maturity (ASM):** There was no significant change in ASM over last 16 generations [(Y= (-0.381x+162.4] as there was no considerable variation from generation to generation. Highest ASM recorded was 172 d (S-22 generation) and lowest was 154.6 d (G-2 generation).

4. **Egg weights:** There was significant (P<0.028) reduction in egg weight recorded at 32 weeks of age over 16 generations [(Y= (-0.10x+56.4] from 56.89 g (S-7 generation) to 54.80 g (S-23 generation). Similarly, there was significant (P<0.002) reduction in egg weight recorded at 40 weeks of age over 13 generations [(Y= (-0.31x+62.4]. It has reduced from 64.65 (S-1 generation) to 57.42 g (S-23 generation). The reduction in egg weights might be due to reduction in body weight at 40 weeks of age as observed over generations.

5. **Egg number to 40 weeks of age:** There was no significant (P<0.326) change in egg number up to 40 weeks of age over last 16 generations [(Y= (-0.426x+50.97] although it improved from 46.1 (S-7 generation) to 53.2 (S-23 generation). Highest 40 weeks egg number recorded was 66.7 eggs (G-1 generation) and lowest was 39.2 (S-8 generation).

Genetic Parameters

In G-2 generation it was reported that egg and body weights were highly heritable and egg production was lowly heritable. ASM was negatively correlated with body weights at 20 and 40 weeks of age both on genetic and phenotypic scales while egg weights were negatively correlated with egg production. In S-16 generation, heritability estimates were high for ASM (0.47) and body weight at 40 weeks of age (0.58). However, heritability estimates of 20 weeks body weight (0.14) and 40 weeks egg production (0.10) were low as estimated on sire component of variance in this line.

Table 18. Performance of PB-1 line with respect to various economic traits

Year	Generation	Body weight (g)			SL at 5 wks (mm)*	BA at 5 wks (°)*	SD	SI	ASM (d)	Egg weight (g)		EN to 40 wks
		5 wks*	20 wks	40 wks						32 wks	40 wks	
97-98	S-7	-	2763	3704	-	-	-	-	168.0	56.89	64.65	46.1
98-99	S-8	-	2658	3409	-	-	-	-	161.7	55.29	60.46	39.2
99-2000	S-9	-	2588	3465	-	-	-	-	171.0	55.64	61.23	40.0
2000-01	S-10	-	2654	3655	-	-	111.0	0.68	166.7	56.63	60.80	60.9
2001-02	3rd generation	737	2512	3488	-	-	-	0.61	-	56.70	59.40	59.4
2002-03	1st pedigree	1065	2726	3993	-	-	165.7	1.16	163.8	56.50	59.30	66.7
2003-04	G-2	988	3099	3733	87.7	87.7	165.7	1.16	154.6	54.80	59.70	63.3
2004-05	G-3/S-15	1015	2741	3524	80.5	101.9	113.0	1.30	161.9	53.95	58.43	58.1
2005-06	S-16	894	2867	3392	76.5	98.4	130.2	1.15	157.6	56.20	61.50	53.6
2006-07	S-17	952	2498	3189	83.1	89.2	145.3	1.05	165.8	55.10	61.20	55.0
2007-08	S-18	924	2676	3767	73.9	89.2	155.5	1.10	164.3	55.14	60.33	57.0
2008-09	S-19	922	2400	3392	81.0	91.0	-	-	166.6	56.00	60.30	61.0
2009-10	S-20	901	2396	3282	-	-	-	-	167.0	54.53	59.54	57.0
2010-11	S-21	840	2368	3266	78.8	89.5	150.0	1.30	171.0	55.30	56.16	52.3
2011-12	S-22	877	2400	3287	78.4	89.8	167.0	1.42	172.0	54.82	56.16	50.7
2012-13	S-23	996	2592	3357	77.0	84.9	172.0	1.35	169.7	54.80	57.42	53.2

Note: *SL: Shank length, BA: Breast angle, SD: Selection differential, SI: Selection intensity, ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex*

7. PB-2 line (Female line of Krishibro - Coloured Broiler)

PB-2 (female line of coloured broiler) was originated from the *inter-se* mating of commercial stocks at PAU, Ludhiana under AICRP on Poultry Breeding for meat (AICRP Annual Report, 1991-92).

Selection criterion at PAU, Ludhiana

This line has undergone mass selection for higher body weight at eight weeks of age coupled with independent culling level selection for egg production trait in females. Subsequently this line was selected for higher body weight at 6 weeks of age using mass selection along with super imposed culling level selection for reproductive traits such as egg production and hatchability (AICRP Annual Report, 1991-92).

Selection criterion at DPR, Hyderabad

The selection program practiced in PB-2 line at DPR, Hyderabad was mass selection for higher body weight at six weeks of age up to S-10 generation. From S-11 generation onwards, the selection criterion was changed from six weeks body weight to five weeks body weight in males and five week body weight as well as higher egg production up to 40 weeks of age in females by independent culling level selection. This type selection is being practiced till present generation (S-23). Average selection differential over 9 generations was 129.5 g with average intensity of selection of 1.067 in 10 generations for body weight at 5 weeks of age.

A pair of PB-2 birds

Effective population size and rate of inbreeding

The information on number of sire and dams used to reproduce each generation, effective population size and rate of inbreeding in PB-2 line is presented in Table 19. Average number of sires and dams used to produce the stock of this line were 52.4 and 246.9 respectively. Effective population size averaged over the years was 171.2 but it has increased from 133.3 (S-7 generation) to 200 (S-22 generation). Cumulative rate of inbreeding was 0.05 and average rate of inbreeding was 0.0029 over generations.

Table 19. Effective population size and rate of inbreeding of PB-2 line

Year	Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
1995-96	S-6	50	150	150.0	0.0033
1996-97	S-7	40	200	133.3	0.0037
1998-99	S-9	49	245	163.3	0.0031
99-2000	S-10	64	320	213.3	0.0023
2000-01	S-11	50	250	166.7	0.0030
2001-02	S-12	50	250	166.7	0.0030
2002-03	S-13	50	250	166.7	0.0030
2003-04	S-14	55	220	176.0	0.0028
2004-05	S-15	55	275	183.3	0.0027
2005-06	S-16	50	250	166.7	0.0030
2006-07	S-17	60	300	200.0	0.0025
2007-08	S-18	57	228	182.4	0.0027
2008-09	S-19	46	227	152.9	0.0032
2010-11	S-20	50	250	166.7	0.0030
2011-12	S-21	50	194	159.0	0.0031
2012-13	S-22	60	300	200.0	0.0025
2013-14	S-23	58	290	163.3	0.0030
Average		52.4	246.9	172.4	0.0029
Cumulative rate of inbreeding					0.0529

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in PB-2 line are presented in Table 20. There was no significant change in fertility over the generations (Y= (-0.007x +77.1)]. Highest fertility recorded was 86% (S-20 generation) and lowest was 69.9% (S-15 generation). However, there was significant (P<0.02) increase in hatchability on FES [Y= (0.75x+76.83)] from 76.8% (S-6 generation) to 92.5% (S-17 generation) and it was 89.2% in latest (S-23) generation. Highest and lowest hatchability recorded on FES were 91.8 (S-21 generation) and 69.0% (S-9 generation) respectively. There was also significant improvement (P<0.049) in hatchability on TES [Y= (0.68x+59.69)] from 63.1% (S-6 generation) to 70.9% (S-23 generation). Highest and lowest hatchability on TES were 75.9% (S-20 generation) and 50.5% (S-9 generation) respectively. Improvement in hatchability traits over generations is in desirable direction since this line is being used as female line for production of 'Krishibro' cross and that will help in production of more number of commercial chicks.

Table 20. Fertility and hatchability traits of PB-2 line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
1995-96	S-6	83.2	76.8	63.1	3771
1996-97	S-7	78.8	86.4	69.7	-
1997-98	S-8	82.9	82.5	68.4	3926
1998-99	S-9	73.1	69.0	50.5	2873
99-2000	S-10	72.6	74.8	53.5	4743
2001-02	S-12	77.0	85.2	65.6	2852
2002-03	S-13	82.4	86.2	71.0	4091
2003-04	S-14	73.0	84.4	61.6	2059
2004-05	S-15	69.9	85.7	59.9	3009
2005-06	S-16	71.5	71.5	61.8	2861
2006-07	S-17	80.4	89.0	71.6	3261
2007-08	S-18	73.4	81.1	60.5	1605
2008-09	S-19	80.5	91.3	73.5	4037
2010-11	S-20	86.0	87.8	75.9	4871
2011-12	S-21	77.7	91.8	71.4	4432
2012-13	S-22	80.3	87.8	70.5	3283
2013-14	S-23	79.5	89.2	70.9	4680
Average		77.8	83.2	65.5	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

Data on the performance of PB-2 line with respect to various growth and production traits over generations are presented in Table 21.

1. **Body weights:** Body weights were recorded at 5, 20 and 40 weeks of age over several generations in PB-2 line. There was no significant change in body weight recorded at 5 weeks of age [Y= (-6.8x+893.2)]. Highest and lowest body weights recorded at 5 weeks of age were 1046 and 694 g respectively in S-18 and S-11 generations. Similarly, there was no significant change in body weight recorded at 20 weeks of age [Y= (13.7x+2324)] although it increased from 2207 (S-2 generation) to 2681 g (S-23 generation) while body weight at 40 weeks of age [Y= (-23.4x+3692.7)] declined from 3285 (S-2 generation) to 2792 g (S-23 generation) but that decline was not significant.

2. **Shank length and breast angle:** There was no significant change in shank

length [Y= (-0.39x+79.8)] recorded at six weeks of age. Highest and lowest shank lengths recorded were 84.5 and 73.0 mm respectively in S-17 and S-23 generations. Similarly, there was no significant change in breast angle [Y= (-0.78x+92.8)] recorded at five weeks of age. Highest and lowest breast angle recorded were 97.5 and 82.6^{o} respectively in S-16 and S-20 generations.

3. **Age at sexual maturity (ASM):** There was no significant change in ASM recorded over generations [(Y= (-0.202x+170.9)] although it has marginally declined from 170.8 (S-2 generation) to 163.8 d (S-22 generation). Highest and lowest ASM recorded were 182.3 and 151 d respectively at S-19 and S-14 generation.

4. **Egg weights:** There was no significant (P<0.380) change in egg weight recorded at 32 weeks of age over 13 generations [(Y= (-0.09x+54.7)]. Highest and lowest egg weights recorded were 55.9 and 51.9 g respectively in S-23 and S-19 generations. Similarly, there was no significant change in egg weight recorded at 40 weeks of age over several generations [(Y= (-0.16x+60.9)]. Highest and lowest egg weights recorded at 40 weeks of age were 64.3 and 56.0 g respectively in S-23 and S-19 generations.

5. **Egg number to 40 weeks of age:** There was no significant change in egg number up to 40 weeks of age over 17 generations [(Y= (0.105x+62.1)]. Highest and lowest 40 weeks egg number recorded were 73.4 and 51.9 respectively in S-2 and S-9 generations.

Table 21. Performance of PB-2 line with respect to various economic traits

Generation	Body weight (g)			SL at 5 wks (mm)*	BA at 5 wks (°)*	SD	SI	ASM (d)	EN 40 wks	Egg weight (g)	
	5 wks*	20 wks	40 wks							32 wks	40 wks
S-2	-	2207	3285	-	-	-	-	170.8	73.4	53.9	61.6
S-3	-	2024	3307	-	-	-	-	179.0	69.3	-	61.7
S-5	-	1929	3055	-	-	-	-	189.0	57.8	-	61.1
S-7	-	2513	3307	-	-	-	-	173.7	59.9	-	60.9
S-9	-	2472	3213	-	-	-	-	164.4	51.9	54.7	59.9
S-10	-	2506	3437	-	-	223	0.91	163.5	57.4	55.8	61.0
S-11	694	2482	3432	-	-	-	0.56	-	59.5	55.9	60.1
S-13	953	2624	3575	-	-	110	1.30	166.6	68.3	54.9	58.7
S-14	919	3139	3502	79.4	85.7	110	1.31	151.0	65.4	52.5	58.0
S-15	921	2796	3529	78.6	98.5	117	1.41	155.0	60.1	52.7	57.1
S-16	840	2728	3207	77.4	97.5	130	1.30	157.0	62.9	54.2	58.2
S-17	868	2461	3533	84.5	86.2	120	1.35	166.2	57.8	54.2	59.0
S-18	1047	2573	3366	73.2	86.8	-	-	166.7	63.1	53.6	58.0
S-19	734	2161	3271	78.1	86.7	113	0.93	182.3	66.2	51.9	56.0
S-20	776	2061	-	73.2	82.6	119	0.79	178.8	67.5	53.5	58.3
S-21	894	2204	2933	78.8	86.8	124	0.81	178.8	67.0	55.9	57.9
S-22	829	2631	3063	80.8	87.0	-	-	163.8	64.0	-	64.0
S-23	713	-	-	73.0	87.4	-	-	-	-	-	-

Note: *SL: Shank length, BA: Breast angle, SD: Selection differential, SI: Selection intensity, ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex*

8. Control Populations

Three control populations such as control broiler, layer control and rural control populations are being maintained at ICAR-DPR, Hyderabad.

A. Control Broiler (CB) Population

Origin

The random bred control broiler (CB) population was developed at University of Agricultural Sciences, Bangalore centre of AICRP on Poultry Breeding for meat using one strain of White Plymouth Rock, two strains of New Hampshire, one strain of Cornish and a strain of synthetic male line. Its pedigree mating started in the year of 1982-83 using 50 sires and 200 dams by natural mating in 1:4 ratio (AICRP Annual Report, 1991-92). Artificial insemination was used to regenerate the population from second generation onwards. This way 50 sires and 250 dams in second generation; 70 sires and 210 dams in third and fourth generations (1984-85 and 1985-86); 110 sires and 300 dams during fifth, sixth and seventh generations (1986-87, 1987-88 and 1988-89) were used to regenerate the stock (Reddy et al., 2013). Subsequently during 1989-90, this pedigreed control broiler population (100 sires and 500 dams) was supplied to the Project Directorate on Poultry, Hyderabad. This random bred control population was maintained up to C-7 generations (1997-98). Later as per the suggestion of Research Advisory Committee, this control population was replaced with the control coloured population as the performance was not comparable with the synthetic lines available at various AICRP centres. Therefore, hatching eggs of a coloured broiler population were procured from CARI and 316 good chicks were hatched (PDP Annual Report 1998-99). Using this population and coloured broiler germplasm available at PDP, a new synthetic coloured broiler population was developed during the year 1998-99. Hatching eggs from this population were supplied to all AICRP centres involved in broiler breeding program (Annual Report 1999-2000). This control population has completed thirteen generations during 2000 to 2014.

Effective population size and rate of inbreeding

Information on number of sires and dams used for regeneration of chicks in each generation and effective population size and rate of inbreeding in each generation is presented in Table 22. Pedigree mating in control population was carried out in such a manner that sires and dams used for mating represented every sire and dam families i.e. each sire in the preceding generation has contributed one male breeder and each dam in the preceding generation contributed one female breeder to the next generation. Average number of sires and dams used over generations for production of CB were 49.1 and 208.7 respectively. Effective population size was calculated using the formula [$Ne=(16NmNf)/(3Nf+Nm)$] that is used for the population in which the sexes are unequal but each dam contribute a daughter and each sire family contribute a son to the next generation and deliberate mating of related individuals is avoided. Effective population size averaged over the years was 242.4. Rate of inbreeding was calculated using the formula $\Delta F= (3/32Nm+1/32Nf)$ that is used for random bred control population. Cumulative rate of inbreeding was 0.0295 and average rate of inbreeding was 0.0021 over generations. These figures suggest that this population has undergone minimum inbreeding and that helped in maintaining the stability of this population for most of the traits by avoiding genetic drift.

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in each generation in control broiler population are presented in Table 23. There was no significant change in fertility over generations [Y= (0.48x+77.7)]. Average fertility over generations was 81.3%. With regard to hatchability on fertile egg set, no significant change was observed [Y= (-0.008x +90.7)] although average hatchability of 90.7% on FES was maintained over the generations. Similarly, there was no significant change in hatchability on total egg set [Y= (0.43x+70.6)] with average hatchability being 73.9%. Fertility and hatchability are fitness traits and report of no significant change in these traits in control broiler population suggests that this population was stable over the generations for these fitness traits.

Table 22. Effective population size and rate of inbreeding of coloured control broiler population

Year	Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
2000-01	C-7/G-0	50	250	250.0	0.0020
2001-02	G-1	55	165	264.0	0.0019
2002-03	G-2	55	220	270.8	0.0018
2003-04	G-3	55	220	270.8	0.0018
2004-05	G-4	55	220	270.8	0.0018
2005-06	G-5	55	220	270.8	0.0018
2006-07	G-6	45	180	221.5	0.0023
2007-08	G-7	55	220	270.8	0.0018
2008-09	G-8	33	132	162.5	0.0031
2009-10	G-9	46	230	230.0	0.0022
2010-11	G-10	44	176	216.6	0.0023
2011-12	G-11	40	200	200.0	0.0025
2012-13	G-12	50	246	249.7	0.0020
2013-14	G-13	49	243	244.9	0.0020
Average		49.1	208.7	242.4	0.0021
Cumulative rate of inbreeding					0.0295

Table 23. Fertility and hatchability traits of control broiler population

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2000-01	C-7/G-0	89.6	92.4	82.8	1737
2001-02	G-1	68.2	89.2	60.8	1277
2002-03	G-2	75.8	94.8	71.8	1294
2003-04	G-3	81.0	87.0	71.0	2364
2004-05	G-4	82.2	87.7	72.1	1238
2005-06	G-5	78.7	88.7	69.9	1407
2006-07	G-6	80.7	92.6	74.7	1051
2007-08	G-7	88.8	92.9	82.5	2006
2008-09	G-8	75.4	85.7	64.7	1319
2009-10	G-9	73.7	93.4	68.8	1939
2010-11	G-10	86.9	92.8	80.7	1670
2011-12	G-11	88.8	94.6	84.0	1851
2012-13	G-12	87.2	94.0	81.9	1583
2013-14	G-13	81.4	83.8	68.2	1765
Average		81.3	90.7	73.9	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic time trend

The data on the growth and production performance of control broiler population over several generations is presented in Table 24.

1. **Body weights:** Body weights were recorded at 4, 5, 20 and 40 weeks of age in control broiler population. There was no significant change in body weight recorded at 4 weeks of age [Y= (-15.4x+497.8)]. There was significant (P<0.020) change in body weight recorded at 5 weeks of age [Y= (-23.7x+893)]. However, no significant change has occurred in body weight recorded at six weeks of age [Y= (-13.6x+1099)]. Body weight at 20 weeks of age [Y= (-46.0x+2711)] has significantly (P<0.007) declined from 2509 (G-0 generation) to 2279 g (G-13 generation). Similarly, there was significant (P<0.036) change in body weight recorded at 40 weeks of age [Y= (-31.6x+3424)].

2. **Shank length and breast angle:** There was no significant change in shank length [Y= (-0.62x+76.99)] recorded at five weeks of age. However, there was significant (P<0.02) reduction in breast angle [Y= (-1.82x+94.5)] recorded at five weeks of age from 88.4 (G-4) to 75.7^{o} (G-13 generation).

3. **Age at sexual maturity (ASM):** There was no significant change in ASM recorded over last 13 generations [(Y= (0.99x+162.9]. Highest and lowest ASM recorded was 194 and 161.9 d respectively in G-10 generation and G-5 generations.

4. **Egg weights:** There was no significant change in egg weight recorded at 32 weeks of age over 14 generations [(Y= (-0.09x+53.2]. Similarly, there was no significant change in egg weight recorded at 40 weeks of age over 14 generations [(Y= (-0.15x+58.1]. Highest and lowest egg weights recorded at 40 weeks of age were 59.6 and 54.7 g respectively in G-0 and G-5 generations. Egg weight recorded at 28 weeks of age was 48.3 and 50.5 g respectively in G-3 and G-4 generations.

5. **Egg number to 40 weeks of age:** There was no significant change in egg number recorded up to 40 weeks of age over last 14 generations [(Y= (-0.02x+57.01]. Highest 40 weeks egg number recorded was 66.7 eggs (G-2 generation) and lowest was 45.9 (G-1 generation).

A pair of control broiler birds

Table 24. Performance of control broiler population with respect to various economic traits

Year	Generation	Body weight (g)					SL at 5 wks (mm)*	B A at 5 wks (º)*	ASM (d)	Egg weight (g)		EN to 40 wks
		4 wks*	5 wks*	6 wks*	20 wks	40 wks		-	-	32 wks	40 wks	
00-2001	G-0	-	-		2509	3150	-	-	176.8	54.4	59.6	50.2
2001-02	G-1	-	822	1060	2536	3256	-	-	163.5	52.0	54.9	45.9
2002-03	G-2	-	872	1141	2776	3370	-	-	163.1	51.1	57.6	66.7
2003-04	G-3	-	731	995	2670	3487	-	-	162.4	53.3	58.1	65.4
2004-05	G-4	-	898	1195	2592	3478	-	88.4	163.8	54.0	58.1	65.1
2005-06	G-5	-	907	1106	2559	3248	-	-	161.9	51.6	54.7	57.5
2006-07	G-6	441	673	891	2130	2886	72.5	96.1	172.8	53.1	58.9	58.7
2007-08	G-7	420	592	783	2457	3336	77.6	87.1	165.5	53.4	56.6	57.3
2008-09	G-8	627	929	1215	2436	3222	76.9	87.1	167.3	54.3	57.0	60.0
2009-10	G-9	402	625	964	1941	3005	75.1	86.1	170.5	51.4	57.3	53.4
2010-11	G-10	377	578	829	1982	2799	75.1	86.1	194.0	51.7	55.1	57.1
2011-12	G-11	336	521	720	1885	2933	73.1	84.1	189.0	51.4	57.3	54.3
2012-13	G-12	492	731	1156	2369	3139	74.1	-	170.0	53.2	56.4	56.6
2013-14	G-13	333	573	993	2279	3033	69.2	75.7	174.0	50.9	55.8	55.82
b±S.E.		-15.4 ± 14.7 ^{NS}	-23.7 ± 8.7	-13.6^{NS} ± 11.76	-46.0 ± 14.2	-31.6 ± 13.4^{NS}	-0.62 ± 0.36^{NS}	-1.8 ± 0.56	1.17^{NS} ± 0.60	-0.09^{NS} ± 0.08	-0.15^{NS} ± 0.10	-0.02^{NS} ± 0.42

Note: *SL: Shank length, BA: Breast angle, ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex*

B. Layer Control (LC) Population

Origin

Initial pedigreed random bred layer control population at PDP, Hyderabad was maintained from 1990-91 to 1995-1996. Subsequently, this population was replaced with new layer control population generated from S-5 generation of the synthetic base layer population that was under mild positive selection for egg production (Reddy et al., 2013) using 70 sires and 350 dams in 1996. LC-2 population was generated using 40 sires and 200 dams. After studying the performance of LC-2 generation up to 64 weeks of age, one female per dam and one male bird from each sire family were selected randomly, likewise 40 sires and 160 dams selected were used to reproduce the LC-3 generation. LC-4 generation was evaluated for production traits up to 64 weeks of age, subsequently, one female per dam and one male from each sire family were selected randomly and thus, a total of 40 sires and 160 dams selected at random were used to regenerate LC-5 population. It was reported that the control population was stable over the previous four generations with regard to egg production up to 40 and 64 weeks of age as that was evident from the observed non significant phenotypic trends for these two traits. LC-6 generation was reproduced using 40 sires and 200 dams selected randomly in such a way that one female per dam and one male from each sire family were represented.

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in layer control line is presented in Table 25. Average number of sires and dams used over generation for regeneration of this line were 44.1 and 191.0 respectively. Effective population size for this control population was calculated using the formula [Ne=(16NmNf)/(3Nf+Nm)] that is used for the population in which the sexes are unequal but each dam contribute a daughter and each sire family contribute a son to the next generation and deliberate mating of related individuals is avoided. Effective population size of this control population averaged over the years was 218.32 but it has decreased from 350.0 (LC-0 generation) to 246.15 (LC-11 generation). Rate of inbreeding was calculated using the formula ΔF= (3/32Nm+1/32Nf). Cumulative rate of inbreeding was 0.0405 while rate of inbreeding averaged over generations was 0.0037.

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in layer control line is presented in Table 26. Highest and lowest recorded fertility was 86.8 (LC-3 generation) and 70.2% (LC-10 generation) respectively. Average fertility of this line over the generations was 78.3% and there was no significant change in fertility over the generations (Y= (-0.430x+81.6)]. Hatchability on FES has improved (P<0.034) over generations from 79.2 (LC-0) to 87.0% (LC-11) and highest hatchability on FES recorded was 92.3% (LC-3 and LC-9 generations) and lowest was 75.9% (LC-1 generation) with average of 86.5% over generations (Y=0.931x+80.60). Average hatchability on TES averaged over generations was 66.6%.

Table 25. Effective population size and rate of inbreeding of layer control population (LC)

Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
LC-0	70	350	350.00	0.00143
LC-1	60	300	300.00	0.00167
LC-2	40	200	200.00	0.00250
LC-3	40	160	196.92	0.00254
LC-4	40	160	196.92	0.00254
LC-5	40	160	196.92	0.00254
LC-6	40	160	196.92	0.00254
LC-7	40	200	200.00	0.00250
LC-8	40	200	200.00	0.00250
LC-9	32	128	157.54	0.00488
LC-10	37	74	169.14	0.00507
LC-11	50	200	246.15	0.00313
Average	44.1	191.0	218.32	0.00282
Cumulative rate of inbreeding				0.0407

Table 26. Fertility and hatchability traits of layer control population

Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
		FES	TES	
LC-0	74.8	79.2	59.2	-
LC-1	73.3	75.9	55.6	4901
LC-2	84.3	81.9	69.1	1492
LC-3	86.8	85.1	70.6	1686
LC-4	86.2	89.4	66.4	-
LC-5	78.2	91.6	71.6	1366
LC-6	76.1	92.3	68.7	1449
LC-7	81.5	89.3	66.2	652 females
LC-8	78.5	91.6	71.9	1715
LC-9	85.1	92.3	78.5	1897
LC-10	70.2	84.2	59.1	1306
LC-11	70.9	87.0	61.7	1704
Average	78.3	86.5	66.6	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic time trend

Data on performance of layer control population over generation with respect to various growth and production traits are presented in Table 27.

1. **Body weights:** Body weights of layer control population were recorded at 16, 40, 52 and 64 weeks of age over generations. There were no significant changes in body weights recorded either at 16 [Y= (-5.68x+1043)] or 40 [Y= (-4.35x+154)] weeks of age. Highest and lowest body weights recorded at 40 weeks of age were 1571 and 1473 g respectively in LC-2 and LC-7 generations. Body weight at 18 weeks of age was 881, 869 and 1055 g respectively in LC-3, LC-4 and LC-5 generations. Body weight recorded at 20 weeks of age was 1318, 1138 and 1081 g in LC-0, LC-1 and LC-11 generations respectively. Body weight at 52 weeks of age was 1498, 1513 and 1600 g in LC-8, LC-9 and LC-10 generations respectively while body weight at 64 weeks of age was 1553, 1672, 1542, 1635 and 1650 g respectively recorded in LC-5, LC-6, LC-7, LC-9 and LC-10 generations.
2. **Age at sexual maturity (ASM):** There was no significant change in ASM [(Y= (0.78x+146.5)] recorded over generations.
3. **Egg weights:** There was no significant change in egg weight recorded at 28 weeks of age from LC-2 to LC-11 generation [(Y=(0.06x+46.06)]. Similarly, there was no significant change in egg weight recorded at 40 weeks of age over 12 generations [(Y= (0.04x+51.4)]. Similarly, Similarly, there was no significant change in egg weight recorded at 64 weeks of age [(Y=(-0.009x+55.04)]. Highest egg weight 64 weeks egg weight was 58.03 and 50.6 g in LC-0 and LC-3 generations respectively.
4. **Egg number to 40 weeks of age:** There was no significant change in egg number recorded up to 40 weeks of age over last 12 generations [(Y= (-0.440x+95.43)].
5. **Egg mass:** Egg mass recorded up to 64 weeks of age were 9992, 10352, 10770, 10152, 11081, 10727 g respectively in LC-5, LC-6, LC-7, LC-8 LC-9 and LC-10 generations.
6. **Egg production up to 64 weeks of age:** It is the primary trait of selection in IWI, IWH and IWK lines. In this (LC) line there was no significant change over generations in this trait [(Y= (-2.45x+209.5)] indicating the stability of this control layer line.
7. **Egg production up to 72 weeks of age:** Initially, the random bred control population was evaluated for egg production up to 72 weeks of age. The egg production recorded up to 72 weeks of age in LC-0 generation was 258.5 numbers. In LC-5 generation egg production up to 72 weeks of age was 213.5. In LC-9 generation, egg production up to 72 weeks of age and egg weight at 72 weeks of age were found to be 222.1±2.06 and 56.4 g respectively.

Control population is stable: Results of phenotypic time trend of various traits in layer control population indicate that this line seems to be stable over generations for many of the traits except for hatchability on fertile eggs set.

Table 27. Performance of layer control population with respect to various economic traits

Year	Generation	Body weight (g)		ASM (d)	Egg number		Egg weight (g)		
		16 wks	40 wks		40 wks	64 wks	28 wks	40 wks	64 wks
1996-97, 1997-98	LC-0	-	-	145.3	103.7	233.1	-	54.2	58.0
1998-99, 1999-00	LC-1	-	1564	140.5	93.8	-	-	52.9	54.3
2000-01, 2001-02	LC-2	1014	1571	150.8	97.6	195.8	47.0	49.4	55.7
2002-03	LC-3	-	1474	158.4	85.5	182.2	45.9	50.5	50.6
2003-04	LC-4	-	1478	156.7	84.2	-	45.6	49.9	-
2004-05, 2005-06	LC-5	-	1515	151.1	95.1	181.0	47.0	50.1	54.6
2006-07, 2007-08	LC-6	978	1511	149.2	93.5	192.1	46.4	51.7	55.1
2008-09	LC-7	1010	1473	148.1	93.1	189.1	45.0	50.9	56.1
2009-10, 2010-11	LC-8	1048	1510	151.6	85.4	173.1	48.3	52.7	-
2011-12	LC-9	954	1508	154.9	91.5	200.6	-	52.9	55.2
2012-13	LC-10	1074	1504	155.4	92.6	194.4	47.3	53.2	55.3
2013-14	LC-11	886	1497	156.4	94.9	-	46.2	51.3	-
b±S.E.		$-5.68^{NS} \pm 8.99$	$-4.35^{NS} \pm 2.9$	$0.78^{NS} \pm 0.39$	$-0.44^{NS} \pm 0.46$	$-2.4^{NS} \pm 1.7$	$0.06^{NS} \pm 0.12$	$0.04^{NS} \pm 0.13$	$-0.009^{NS} \pm 0.21$

Note: *ASM: Age at sexual maturity, wks: weeks*

C. Rural Control Population

Origin

The random bred rural control population was evolved from the PD-2 line (Female line of Vanaraja) by random mating (Pooled semen) during 2011-12. This control line has undergone only three generations of random mating and it is too early to determine if this line has stabilised yet. Average of number of sires and dams used were 18.3 and 61.7 respectively (Table 28). Average effective population size and rate of inbreeding were 88.96 and 0.0056 respectively while cumulative rate of inbreeding recorded so far was 0.01723. Average fertility observed was 89.28% while average hatchability on FES and TES was 88.99 and 79.52 respectively (Table 29).

Table 28. Effective population size and rate of inbreeding in rural control line

Year	Generation	No. of Sires	No. of Dams	Ne (Effective population size)	ΔF (Rate of inbreeding)
2011-12	G-1	20	80	98.46	0.00508
2012-13	G-2	15	45	72.00	0.00694
2013-14	G-3	20	60	96.00	0.00521
Average		18.3	61.7	88.96	0.00562
Cumulative rate of inbreeding					0.01723

Table 29. Fertility and hatchability traits of rural control line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2011-12	G-1	88.99	92.74	82.53	345
2012-13	G-2	94.02	89.28	83.95	450
2013-14	G-3	84.84	84.95	72.07	542
Average		89.28	88.99	79.52	-

FES: Fertile eggs set, TES: Total eggs set

The data on growth and production traits of this line are presented in Table 30. In G-0 generation, the egg weight at 24 and 30 weeks of age was 44.1 and 49.0 g respectively. The egg production up to 30 weeks of age was 49 eggs in the control population.

Table 30. Growth and production traits of rural control line

Year	Generation	SL 6 wks (mm)	B wt 6 wks (g)	B wt 20 wks (g)	B wt 40 wks (g)	ASM (d)	Egg No to 40 wks
2011-12	G-0	72.5	449	-	-	158.8	-
2012-13	G-1	67.9	491	2346	2581	159.8	83.65
2013-14	G-2	69.2	491	2390	2634	163.4	78.50

SL: Shank lenght, wks: weeks, Bwt: Body weight, ASM: Age at sexual maturity

9. Major Gene lines

The work on development of gene lines such as naked neck ('Na' earlier designated as 'NG') and sex linked Dwarf gene ('dw' earlier designated as 'DG') broiler lines was started under the program - III titled '*Development of gene lines with single genes such as Naked Neck (Na) and sex linked Dwarf (dw) genes for using as source of single genes relevant for tropical poultry production*' in the year 1997-98.

A. Naked neck broiler gene (Na) line

Origin

Naked neck broiler gene line was originated from birds with Nana phenotype from synthetic population, an entry from CARI for 5th broiler random sample test conducted at PDP, Hyderabad during 1994-95 (PDP Annual Report, 1995-96). This line was subjected to mass selection for higher body weight at six weeks of age in both Nana and nana phenotypes in both male and female birds. Male birds were further selected for high antibody titre to sheep red blood cells (SRBCs) during 1997-98. In the year 1998-99, while generating NG-98 from NG-97 generation, plumage colour, egg size and egg number were considered as the main criteria in selecting the breeders. In NG-98 generation, selection of birds was based on six weeks body weight and the selection for high SRBCs titre was superimposed on selected birds. As the number of birds available for breeding was very less in NG-98 generation, the NG-99 generation was reproduced with all available naked neck females and males (nana) from coloured heavy weight line. Pooled semen of coloured heavy weight line was used to inseminate naked neck female birds instead of semen from pedigreed necked neck sires in this generation. All the females available at the end of 40 weeks of age were used to produce NG-2000 (NG-00) population.


A pair of Naked neck broiler gene birds

Selection criterion

The selection criterion practiced in naked neck gene line was mass selection for higher body weight at six weeks of age. From NG-00 generation to S-6 generation, this kind of selection was continued to be practiced. Due to paucity of housing space at the institute, this population is being maintained as 20 sire base pedigreed resource population with mild selection for higher body weight at 6 weeks of age.

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in naked neck gene line is presented in Table 31. Average number of sires and dams used to reproduce 'Na' line over the generations was 34.7 and 122.6 respectively. Effective population size averaged over the years was 107.8 but it has decreased from 81.1 (S-0 generation) to 57 (S-12 generation). While cumulative rate of inbreeding was 0.0688 and rate of inbreeding averaged over the generations was 0.0049.

Table 31. Effective population size and rate of inbreeding of Naked neck gene (Na) line

Year	Generation	Sires	Dams	Ne (Effective population size)	ΔF (Rate of inbreeding)
2000-01	NG-99	26	92	81.1	0.0062
2001-02	NG-00/S-0	25	100	80.0	0.0063
2002-03	NG-01/S-1	40	160	128.0	0.0039
2003-04	NG-02/S-2	36	144	115.2	0.0043
2004-05	NG-03/S-3	30	120	96.0	0.0052
2005-06	S-4	50	150	150.0	0.0033
2006-07	S-5	39	117	117.0	0.0043
2007-08	S-6	40	120	120.0	0.0042
2008-09	S-7	40	160	128.0	0.0039
2009-10	S-8	40	158	127.7	0.0039
2010-11	S-9	35	140	112.0	0.0045
2011-12	S-10	36	108	108.0	0.0046
2012-13	S-11	30	90	90.0	0.0056
2013-14	S-12	19	57	57.0	0.0088
Average		34.7	122.6	107.9	0.0049
Cumulative rate of inbreeding					0.0688

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in 'Na' line are presented in Table 32. There was no significant (P<0.315) change in fertility over the generations (Y=(-0.42x +90.4)]. Highest fertility recorded was 93.1% (S-1 generation) and lowest was 75.5% (S-8 generation). There was no significant (P<0.94) change in hatchability on FES [Y=(-0.002x+80.6)]. Highest hatchability on FES recorded was 86% (S-10 generation) and lowest was 74.0% (S-3 generation). Similarly, there was no significant (P<0.698) change in hatchability on TES [Y=(-0.21x+70.9)]. Highest and lowest hatchability on TES were 80.0 (S-10 generation) and 58.9% (S-12 generation) respectively.

Table 32. Fertility and hatchability traits of Naked neck gene (Na) line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2001-02	NG-00/S-0	92.7	85.2	79.0	852
2002-03	NG-01/S-1	93.1	82.8	72.3	1284
2003-04	NG-02/S-2	92.6	78.4	69.0	2312
2004-05	NG-03/S-3	83.0	74.0	61.0	1842
2005-06	S-4	84.2	79.7	67.1	1383
2006-07	S-5	83.8	76.5	64.1	779
2007-08	S-6	89.1	82.4	73.0	871
2008-09	S-7	90.2	80.8	72.0	916
2009-10	S-8	75.5	82.0	61.0	939
2010-11	S-9	88.1	81.0	71.4	827
2011-12	S-10	92.0	86.0	80.0	816
2012-13	S-11	91.1	82.0	74.7	610
2013-14	S-12	81.2	75.2	58.9	385
Average		87.43	80.59	70.04	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

The data on the performance of naked neck broiler gene line with respect to various growth and production traits over the generations are presented in Table 33.

1. **Body weights:** Body weights were recorded at 4, 6, 20 and 40 weeks of age over generations in naked neck broiler gene line. There was no significant change in body weight at 4 weeks of age [Y= (-4.8x+552.5)]. Highest and lowest body weights recorded at 4 weeks of age were 651 and 411 g respectively in S-7 and S-3 generations. Similarly, there was no significant change in body weight recorded at 6 weeks of age [Y= (-3.58x+1013)]. Highest and lowest body weights recorded at 6 weeks of age were 878 and 1315 g respectively in S-4 and S-7 generations. Body weight at 20 weeks of age [Y= (-37.4x+2698)] has declined (P<0.055) from 2733 g (S-0 generation) to 2381 g (S-1 generation). There was significant (P<0.018) decline in body weight recorded at 40 weeks of age [Y= (-41.3x+3442)] from 3326 (S-0) to 3007 g (S-11 generation).

2. **Age at sexual maturity (ASM):** There was non-significant decline in ASM over last 11 generations [(Y=(-1.32x+172.5)] from 166.9 (S-0) to 161.4 d (S-11 generation).

Table 33. Performance of Naked neck broiler gene line with respect to various economic traits

Year	Generation	Body weight (g)				ASM (d)	Egg weight (g)			EN to 40 wks
		4 wks*	6 wks*	20 wks	40 wks		28 wks	32 wks	40 wks	
2002-03	NG-01/S-1	584	1110	2733	3326	166.9	-	55.7	59.3	55.2
2003-04	NG-02/S-2	531	918	2755	3635	160.2	53.9	57.2	62.3	52.3
2004-05	NG-03/S-3	411	917	2756	3236	171.8	54.4	57.5	62.3	51.8
2005-06	S-4	467	878	2349	3158	175.8	53.5	57.6	61.4	62.6
2006-07	S-5	609	1156	2130	-	176.0	-	-	62.4	53.4
2007-08	S-6	594	1043	2396	3223	169.4	52.6	56.9	61.8	54.4
2008-09	S-7	651	1315	2568	3174	157.3	53.5	56.3	61.0	63.8
2009-10	S-8	510	1059	2456	3047	160.0	53.2	55.8	60.0	64.2
2010-11	S-9	439	1015	2444	3154	157.1	54.5	58.0	63.1	66.4
2011-12	S-10	510	1059	2236	3184	154.3	52.2	55.6	61.3	64.0
2013-14	S-11	452	913	2381	3007	161.4	52.3	59.6	61.3	65.8

Note: *ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex*

3. **Egg weights:** There was no significant change in egg weight recorded at 28 weeks of age [(Y= (-0.1734x+54.2)]. However, there was non-significant improvement in egg weight recorded at 32 weeks of age [(Y= (0.124x+56.3)] from 55.7 (S-1) to 59.6 g (S-11 generation). There was non- significant change in egg weight recorded at 40 weeks of age over 10 generations [(Y= (-0.004x+61.2)]. Highest and lowest egg weights recorded at 40 weeks of age were 63.1 and 59.3 g respectively in S-9 and S-1 generations.

4. **Egg number to 40 weeks of age:** There was significant (P<0.003) increase in egg number recorded up to 40 weeks of age over last 11 generations [(Y= (1.429x+50.9)] from 55.2 (S-0) to 65.8 (S-11) generation.

Genetic parameters

Data on genetic parameters such as heritability and genetic correlations of juvenile traits of naked neck broiler gene line estimated on sire component of variance are presented in Table 34. Heritability estimates of body weight at four weeks of age ranged from moderate to high except during S-4 and S-5 generations in which low heritability estimates were recorded. Similarly, heritability estimates of body weight at six weeks of age ranged from moderate to high except in S-4 and S-5 generations. Genetic correlations between four and six weeks body weight were positive and mostly high in magnitude. Heritability estimates of shank length measured at six weeks of age were in the range of moderate to high.

Table 34. Genetic parameters of juvenile traits in Naked neck broiler gene line

Year	Generation	$h^2_{(Sire)}$			r_{gS} (between 4 and 6 wks body weight)
		B wt at four wks	B wt at six wks	SL at six wks	
2002-03	NG-01/S-1	0.14±0.08	0.41±0.15	-	-
2003-04	NG-02/S-2	0.21±0.10	0.14±0.08	-	0.88±0.11
2004-05	NG-03/S-3	0.25±0.06	0.40±0.09	-	0.79±0.13
2005-06	S-4	0.16±0.08	0.06±0.05	-	0.56±0.33
2006-07	S-5	0.04±0.14	0.10±0.12	-	0.96±0.15
2007-08	S-6	0.74±0.23	0.36±0.19	-	0.85±0.14
2009-10	S-8	0.39±0.13	0.27±0.11	0.37±0.14	-
2010-11	S-9	0.42±0.19	0.37±0.14	0.29±0.19	-

Note: *B wt; Body weight, SL: Shank length, r_{gS}: Genetic correlation on sire component of variance*

B. Dwarf Broiler Gene (dw) line

Origin

Dwarf broiler line was evolved from mating of few Dwarf females (*dw-*) and few males of heterozygous at dwarf locus (*Dwdw*) during 1995-96 (Annual Report, 1995-96). At the end of first generation, only 12 dwarf females were available for recording production traits and regeneration. Subsequent generation was reproduced using these 12 dwarf females and normal looking heterozygous males. In the year 1997-98, dwarf females (84 numbers) were selected based on early egg size (32 weeks) and egg production for regenerating the dwarf females and heterozygous dwarf males of the next generation (DG-97). The DG-98 generation in six hatches was generated during the year 1998-99 using 119 dwarf females. During 1998-99 dams were selected based on egg weights at 32 weeks of age and the egg number up to 60 weeks of age while 12 sires with *Dwdw* genotype were selected from 19 sires which were selected for high SRBCs titre. The next generation (DG-99) was reproduced using these selected birds. From DG-99 generation onwards efforts were made to develop pure dwarf gene line. Therefore, only males of *dwdw* genotype and females of *dw-* genotype were selected and from these selected birds male birds having SRBC titre of 7 and above were utilized for regeneration of DG-99 generation.

During 1999-2000, efforts were made to improve the body weight of dwarfs by introducing the genes from coloured synthetic broiler dam line in DG-99 generation. Homozygous dwarfs (dwdw) males, dw- females and few *Dwdw* males were retained at 10th week of age. Due to the introduction of coloured synthetic broiler dam line in dwarf line, birds in DG-00 generation were segregating for dwarf as well as normal (non dwarf) genes. From this population only dwarf birds were retained and normal birds were culled and mild selection pressure was applied. After recording the performance for 40 weeks, 40 sires and 200 dams were used to regenerate DG-01 population.

A pair of Dwarf broiler gene line birds

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in Dwarf gene line was presented in Table 35. Effective population size averaged over the years was 111.5 but it has decreased from 81.1 (S-0 generation) to 57 (S-12 generation). Cumulative rate of inbreeding was 0.057 and average rate of inbreeding was 0.0047.

Table 35. Effective population size and rate of inbreeding of Dwarf broiler gene line

Year	Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (∆F)
2002-03	DG-01/S-1	40	200	133.3	0.0037
2003-04	DG-02/S-2	40	160	128.0	0.0039
2004-05	DG-03/S-3	39	156	124.8	0.0040
2005-06	DG-04/S-4	30	120	96.0	0.0052
2006-07	S-5	50	150	150.0	0.0033
2007-08	S-6	38	152	121.6	0.0041
2008-09	S-7	40	120	120.0	0.0042
2009-10	S-8	38	113	113.7	0.0044
2010-11	S-9	30	120	96.0	0.0052
2011-12	S-10	30	90	90.0	0.0056
2012-13	S-11	35	105	105.0	0.0048
2013-14	S-12	20	60	60.0	0.0083
Average		35.8	128.8	111.5	0.0047
Cumulative rate of inbreeding					0.0567

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in Dwarf broiler gene line are presented in Table 36. Fertility and hatchability on FES and TES averaged over the generations were 84.2, 89.1 and 77.5% respectively. There was no significant change in fertility recorded over generations (Y= (-0.249x+85.6)]. Highest fertility recorded was 89.7% (S-2 generation) and lowest was 77.1% (S-12 generation). There was no significant (P<0.405) change in hatchability on FES [Y= (0.453x+85.9)]. Highest hatchability on FES recorded was 95.3% (S-11 generation) and lowest was 69.7% (S-4 generation). Similarly, there was no significant change in hatchability on TES [Y= (-0.112x+78.2)]. Highest and lowest hatchability on TES were 91.0% (S-4 generation) and 63.5% (S-12 generation) respectively.

Table 36. Fertility and hatchability traits of Dwarf broiler gene line

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2001-02	DG-00	83.5	87.1	73.0	1306
2002-03	DG-01/S-1	87.7	91.5	80.2	2977
2003-04	DG-02/S-2	89.7	90.3	74.5	1437
2004-05	DG-03/S-3	83.0	86.0	72.0	1952
2005-06	DG-04/S-4	76.6	69.7	91.0	1839
2006-07	S-5	85.6	89.4	76.6	1143
2007-08	S-6	81.7	92.3	75.4	1069
2008-09	S-7	83.2	90.4	75.2	772
2009-10	S-8	85.8	96.0	82.4	898
2010-11	S-9	87.0	93.5	81.3	1035
2011-12	S-10	82.1	94.2	78.2	721
2012-13	S-11	86.8	95.3	82.7	649
2013-14	S-12	77.1	82.4	63.5	399
Average		84.2	89.1	77.5	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

The data on various growth and production traits of Dwarf broiler gene line over several generations are presented in Table 37.

1. **Body weights:** Body weights were recorded at 4, 6, 20 and 40 weeks of age over generations in Dwarf broiler gene line. There was no significant change in body weight recorded at 4 weeks of age [Y= (-0.005x+409)] over generations. Highest and lowest body weights recorded at 4 weeks of age were 502 and 272 g respectively in S-7 and S-3 generations. Similarly, there was no significant change in body weight recorded at 6 weeks of age [Y= (5.31x+770)]. Highest and lowest body weights recorded at 6 weeks of age were 982 and 601 g respectively in S-7 and S-3 generations. Body weight at 20 weeks of age [Y= (-15x+2214)] has declined non-significantly from 2260 (DG-99 generation) to 2113 g (S-11 generation). There was significant (P<0.013) reduction in body weight recorded at 40 weeks of age [Y= (-28.6x+2881)] from 3046 (DG-99) to 2673 g (S-11 generation).

2. **Age at sexual maturity (ASM):** There was significant (P<0.031) decline in ASM over last 14 generations [(Y= (-1.21x+159.5)] from 163.6 (DG-98) to 138.9 d (S-11 generation).

3. **Egg weights:** There was no significant change in egg weight recorded at 28 weeks of age [(Y= (-0.339x+49.3)]. Similarly there was no significant change

Table 37. Performance of Dwarf broiler gene line with respect to various economic traits

Year	Generation	Body weight (g)				ASM (d)	Egg weight (g)			EN to 40 wks
		4 wks*	6 wks*	20 wks	40 wks		28 wks	32 wks	40 wks	
98-99	DG-98	-	872	-	-	163.6	-	54.3	57.9	68.8
99-2000	DG-99	428	835	2260	3046	148.7	-	52.2	56.9	66.7
2001-02	DG-00	-	-	2126	2832	154.8	-	51.6	58.2	66.4
2002-03	DG-01/S-1	470	825	2177	2740	148.7	47.7	52.9	56.1	65.9
2003-04	DG-02/S-2	454	707	2259	2851	146.6	47.7	51.2	57.0	74.0
2004-05	DG-03/S-3	272	601	2219	2594	162.3	49.0	51.3	55.8	57.1
2005-06	DG-04/S-4	259	607	2104	2563	151.5	48.9	52.3	56.5	59.3
2006-07	S-5	-	833	1929	-	162.9	-	-	55.1	55.7
2007-08	S-6	479	945	1954	2634	146.6	49.9	51.7	55.9	43.5
2008-09	S-7	502	982	2181	2638	144.8	48.9	51.2	57.0	69.7
2009-10	S-8	457	847	1946	2511	154.9	46.3	50.7	55.3	79.1
2010-11	S-9	329	824	2124	2649	148.1	44.9	48.8	55.0	62.9
2011-12	S-10	454	845	2032	2616	133.3	43.5	47.8	54.1	68.1
2012-13	S-11	392	772	2113	2673	138.9	48.0	53.8	55.6	75.2

Note: *ASM: Age at sexual maturity, EN: Egg number, wks: weeks, *Pooled sex* in egg weight recorded at 32 weeks of age [(Y= (-0.233x+53.15)] although it marginally declined from 54.3 (DG-98) to 53.8 g (S-11 generation). However, there was significant (P<0.001) reduction in egg weight recorded at 40 weeks of age [(Y= (-0.211x+57.8)] from 57.9 (DG-98 generation) to 55.6 g (S-11 generation).

4. **Egg number to 40 weeks of age:** There was non-significant increase in egg number recorded up to 40 weeks of age over last 14 generations [(Y= (0.21x+63.6] from 68.8 (DG-98) to 75.2 (S-11 generation).

Genetic parameters

Data on genetic parameters such as heritability and genetic correlations of juvenile traits of Dwarf broiler gene line estimated on sire component of variance are presented in Table 38. Heritability estimates of body weight at four weeks of age ranged from moderate to high except during S-4 generation in which low hereditability estimates were recorded. Similarly, heritability estimates of body weight at six weeks of age ranged from moderate to high except in S-4 and S-5 generations. Genetic correlations between four and six weeks body weight were positive and mostly high in magnitude in different generations. Heritability estimates of shank length measured at six weeks of age were in the range of moderate to high.

Heritability estimates of ASM (0.18) was moderately heritable while that of body weight at 20 weeks (0.40), egg number up to 40 weeks of age (0.31) and egg weights at 28 (0.42), 32 (0.35) and 40 (0.42) weeks of age were highly heritable in DG-01 generation as determined on sire component of variance. Heritability estimates of body weight at forty weeks of age (0.33), ASM (0.63), egg production up to 40 weeks of age (0.61), egg weight at 28 (0.46), 32 (0.82) and 40 weeks (0.83) of age were high while that of body weight at 20 weeks of age (0.15) was low as estimated on sire component of variance in DG-02 generation.

Table 38. Genetic parameters of juvenile traits in Dwarf broiler gene line

Year	Generation	$h^2_{(Sire)}$			r_{gS} (between 4 and 6 wks body weight)
		B wt at four wks	B wt at six wks	SL at six wks	
2002-03	DG-01/S-1	0.28±0.08	0.24±0.07	-	-
2003-04	DG-02/S-2	0.33±0.12	0.39±0.14	-	0.73±0.12
2004-05	DG-03/S-3	0.40±0.15	0.35±0.18	-	0.80±0.16
2005-06	DG-04/S-4	0.16±0.09	0.13±0.08	-	0.45±0.32
2006-07	S-5	0.31±0.12	0.17±0.11	-	0.96±0.25
2007-08	S-6	0.44±0.17	0.43±0.17	-	0.96±0.25
2009-10	S-8	0.26±0.09	0.58±0.17	0.38±0.12	-
2010-11	S-9	0.36±0.19	0.48±0.27	0.26±0.13	-

Note: *B wt : Body weight, SL: Shank length, wks: weeks,* r_{gS}*: Genetic correlation on sire component of variance*

10. Layer lines

Origin

The origin of pure line germplasm of layer populations maintained at Directorate of Poultry Research, Hyderabad started from CARI, Izatnagar. Populations of IWH, IWI, IWK and control lines were brought to Andhra Pradesh Agricultural University (APAU), Hyderabad and from there to PDP, Hyderabad. Fertile eggs of IWI, IWH and IWK were obtained from AICRP on Poultry Breeding, Hyderabad and hatched at PDP, Hyderabad in the month of December 1995 (Annual Report, 1995-96). In initial generation (S-0), no selection for any of the traits was practiced and the germplasm was evaluated for production traits up to 72 weeks of age (Annual Report, 1996-97). Egg production up to 72 weeks of age in IWI, IWH and IWK lines was 261.2, 261.3 and 255.8 respectively.

Selection criterion

In S-1 generation, birds in all three lines were selected based on Osborne index for higher egg production up to 56 weeks of age. However, from S-2 generation onwards the criterion of selection used was Osborne index for higher egg production up to 64 weeks of age in all three lines (IWH, IWI and IWK).

IWK line

During initial generations (2001-02, 2002-03 and 2003-04), IWK line was selected for improved feed efficiency during 21-64 weeks of age. From S-5 generation onwards, the selection criterion was changed to Osborne index for higher egg mass up to 64 weeks of age in this line (Annual Report, 2004-05). However, from the year 2010 onwards, the selection program was further changed to index selection for higher egg weight at 28 weeks of age and egg production up to 64 weeks of age.

A pair of White Leghorn layer birds

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in IWK line is presented in Table 39. Average number of sires and dams used to regenerate this line over generations was 40.5 and 179.5 respectively. Effective population size averaged over the years was 131.8 but it has increased from 108.4 (S-0 generation) to 160 (S-10 generation). Cumulative rate of inbreeding was 0.0039 and average rate of inbreeding was 0.0385 over generations.

Table 39. Effective population size and rate of inbreeding in IWK line

Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
S-1	35	120	108.4	0.0039
S-2	40	160	128.0	0.0045
S-3	35	140	112.0	0.0043
S-4	35	175	116.7	0.0037
S-5	40	200	133.3	0.0037
S-6	40	200	133.3	0.0037
S-7	40	200	133.3	0.0037
S-8	40	200	133.3	0.0031
S-9	50	200	160.0	0.0031
S-10	50	200	160.0	0.0031
S-11	50	250	166.3	0.0030
Average	41.4	185.9	135.8	0.0038
Cumulative rate of inbreeding				0.0415

Fertility and hatchability

The data on fertility and hatchability and number of chicks hatched in IWK line are presented in Table 40. There was a slight improvement in fertility over the generations (Y= (0.364x+74.9)]. Highest fertility recorded was 83.1% (S-1 generation) and lowest was 73.0% (S-0 generation). There was no significant change in hatchability on FES [Y= (0.75x+77.01)]. Highest hatchability (FES) recorded was 88.1% (S-8 generation) and lowest was 71.2% (S-2 generation).

Table 40. Fertility and hatchability traits of IWK line

Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
		FES	TES	
S-0	73.0	75.1	59.5	2674
S-1	83.1	87.2	72.5	2903
S-2	74.3	71.2	52.9	1395
S-3	76.4	82.7	63.2	2580
S-4	74.6	-	-	1172
S-5	76.6	78.8	60.3	1354
S-6	73.9	83.5	65.3	1348
S-7	76.0	81.7	-	2085, 714 (F)
S-8	77.3	88.1	-	1593
S-9	82.9	85.9	-	2061
S-10	80.7	80.0	64.5	1580
S-11	78.4	87.9	68.9	2304
Average	76.5	83.6	63.4	-

FES: Fertile eggs set, TES: Total eggs set

Phenotypic response

The data on performance of IWK line over several generations with respect to various growth and production traits are presented in Table 41.

1. **Body weights:** Body weights of IWK line were recorded at 16, 40, 52 and 64 weeks of age over generations. There was no significant change in body weight recorded at 40 weeks of age [Y= (-2.01x+1449)]. Highest and lowest body weights recorded at 40 weeks of age were 1524 and 1372 g respectively in S-2 and S-11 generations. Body weight recorded at 18 weeks of age was 1045 g during S-5 generation while body weight recorded at 20 weeks of age was 1207 and 1089 g in S-0 and S-3 generations respectively.

2. **Age at sexual maturity (ASM):** There was no significant change in ASM [(Y= (0.694x+141.6)] over generations although ASM increased from 137 (S-1) to 147.8 days as recorded in latest generation.

3. **Egg weights:** There was no significant change in egg weight recorded at 40 weeks of age over 12 generations [(Y= (-0.01x+53.6)]. Highest and lowest egg weights recorded at 40 weeks of age were 54.8 and 52.3 g respectively in S-0 and S-2 generations. Similarly, there was no significant change in egg weight recorded at 28 weeks of age [(Y= (-0.08x+46.8)].

4. **Egg number:** There was no significant change in egg number recorded up to 40 weeks of age over last 12 generations [(Y= (-0.56x+106.1]. Similarly, there was no significant change in egg number recorded up to 64 weeks of age [(Y= (-0.98x+211.97]. Highest and lowest recorded egg production up to 64 weeks of age was 231.0 and 174.2 in S-10 and S-8 generations respectively.

5. **Egg mass:** There was improvement in egg mass recorded up to 64 weeks of age [(Y= (332x+10267] albeit non-significant. Highest and lowest egg mass recorded at 64 weeks of age was 10388 (S-8) and 12824 g (S-10) respedtively. Highest and lowest egg mass recorded at 40 weeks of age was 5653 and 5380 g respectively in S-3 and S-6 generations.

6. **Egg production up to 72 weeks of age:** Egg production up to 72 weeks of age recorded in IWK line was 255.8, 221.9, 240 and 269.8 eggs respectively in S-0, S-5, S-9 and S-10 generations. Figures reveal that there was improvement in egg production up to 72 weeks of age in this line. Egg weight at 72 weeks of age as recorded in S-5 generation was 60.77 g.

Genetic parameters

S-1 generation: Heritability estimates of ASM (0.05) and 40 weeks egg production (0.05) were low while that of body weight at 20 weeks of age (0.20), egg weight (0.27) and body weight at 40 weeks (0.30) of age were moderate as estimated from sire component of variance in S-1 generation.

S-2 generation: In this generation, heritability estimates of ASM (0.30), 40 weeks body weight (0.21), 40 weeks egg number (0.27) and 40 weeks egg mass (0.25) were moderate while those of 16 weeks body weight (0.49), egg weight at 28 weeks (0.33) and 40 weeks of age (0.37) were high as estimated on sire component of variance. The genetic correlation of 40 weeks egg mass with ASM was negative and high in magnitude (-0.99) while that with 40 weeks egg productioin (0.87) was high and positive. Genetic correlation was positive and low with 16 weeks body weight (0.10) and 40 weeks body weight (0.17) and negative and moderate with 40 weeks egg weight (-0.30) as determined on sire component basis.

S-3 generation: Heritability of 20 weeks body weight (0.27), ASM (0.15), 40 weeks egg production (0.10), feed/dozen of eggs (0.13) and residual feed consumption (0.09) was low while that of egg weight at 28 weeks (0.44) and 40 weeks (0.41), 40 week body weight (0.48) was high as estimated on sire component of variance in S-3 generation.

S-6 generation: In this generation heritability estimates of body weight at 52 (0.18) and 64 (0.12) weeks of age, egg weight at 52 (0.15) and 64 weeks (0.12±0.08) of age were low. Heritability estimates of egg production up to 52, 64 and 72 weeks of age were 0.19±0.10, 0.25±0.16 and 0.18±0.33 (mostly low to moderate as estimated on sire component of variance) respectively.

Table 41. Performance of IWK line with respect to various economic traits

Year	Generation	Body weight (g)				ASM (d)	Egg weight (g)			Egg number		Egg mass at 64 wks (g)
		16 wks	40 wks	52 wks	64 wks		28 wks	40 wks	64 wks	40 wks	64 wks	
96-97, 97-98	S-0	-	1484	-	-	-	-	54.8	-	107.2	219.7	-
98-99, 99-00	S-1	1114	1373	-	-	137.2	43.9	52.6	-	103.6	-	-
00-01, 01-02	S-2	935	1524	-	-	144.0	48.1	52.3	-	108.3	-	-
2002-03	S-3	-	1386	-	1524	-	46.2	53.4	56.9	113.6	223.1	-
2003-04	S-4	-	1390	-	-	-	-	53.4	-	95.3	-	-
04-05, 05-06	S-5	-	1510	-	1601	154.4	49.5	54.4	58.9	98.6	189.3	10558
06-07, 07-08	S-6	966	1410	1473	1583	144.3	49.1	54.2	58.1	101.0	199.1	11601
07-08, 08-09	S-7	961	1392	-	1470	151.8	48.8	54.1	58.3	97.8	191.8	11229
09-10, 10-11	S-8	1062	1466	1491	-	149.1	49.3	53.8	-	95.9	174.2	10388
10-11, 11-12	S-9	985	1454	1478	1523	145.0	-	53.6	56.3	99.2	212.7	11980
12-13, 13-14	S-10	1009	1464	1538	1565	148.0	46.6	53.0	55.5	104.3	231.0	12824
2014-15	S-11	837	1372	-	-	147.8	45.4	53.0	-	104.9	-	-

Note: *ASM: Age at sexual maturity, wks: weeks*

IWH and IWI lines

Selection in IWH and IWI lines: Selection program practiced in IWH and IWI lines from the S-2 generation to till replacement of these lines was Osborne index for higher egg production up to 64 weeks of age. The production performance of IWH and IWI lines from S-0 to S-7 generation is presented in Table 42 and 43 respectively. Egg mass recorded in S-6 and S-7 generations in IWH line was 10507 and 11205 g respectively and that in IWI line was 11660 and 11060 g respectively.

Table 42. Production performance of IWH line up to S-7 generation

Generation	Body wt at 40 wks (g)	ASM (d)	Egg Numbers		Egg weight (g)		
			40 wks	64 wks	28 wks	40 wks	64 wks
S-0	1630	135	118.8	-	-	53.5	
S-1	1424	137	110.9	177.0	-	50.3	54.4
S-2	1546	139	116.6	-	45.9	48.5	
S-3	1332	144	106.4	203.1	44.7	49.4	51.6
S-4	1376	152	105.7	-	44.7	49.6	
S-5	1449	158	104.1	200.7	46.2	50.3	54.7
S-6	1401	141	107.9	205.6	46.1	50.5	54.4
S-7	1414	146	105.2	200.9	45.2	50.9	55.8

Table 43. Production performance of IWI line up to S-7 generation

Generation	Body wt. at 40 wks (g)	ASM (d)	Egg Numbers		Egg weight (g)		
			40 wks	64 wks	28 wks	40 wks	64 wks
S-0	1644	143	110.4	-	-	53.5	-
S-1	1479	139	109.5	179.7	-	51.0	54.3
S-2	1538	146	111.0	-	46.2	47.9	-
S-3	1367	154	100.0	203.8	45.3	49.9	50.5
S-4	1385	154	97.8	-	45.8	50.1	-
S-5	1449	158	105.1	205.2	47.6	49.5	55.5
S-6	1419	148	109.2	214.7	46.5	50.8	54.4
S-7	1381	149	105.7	201.1	45.4	50.3	55.5

Note: *ASM: Age at sexual maturity, wt: weight, wks: weeks*

Production traits: There was not much change in body weight recorded at 40 weeks of age over generations. However, age at sexual maturity increased from 135 to 146 and 143 to 149 days in IWH and IWI lines respectively resulting in reduction in 40 weeks egg production by 13.6 and 5.2 eggs respectively in IWH and IWI line with little or no change in egg weight.

Replacement of IWH and IWI populations: As per the recommendation of the Quinquennial Review Team (QRT), populations of IWH and IWI lines maintained at PDP, Hyderabad were replaced with those from Central Avian Research Institute, Izatnagar maintained under AICRP on Poultry Breeding for egg. A total of 2000 fertile eggs of each line (IWH and IWI lines) were procured and hatched during the year 2008-09 (Annual Report, 2008-09). IWH and IWI lines were evaluated for egg production traits up to 72 weeks of age. It was observed that the 72 weeks egg production was higher in IWH (257.5) as compared to IWI line (252.9). Egg production up to 72 weeks of age was 282 and 279 respectively in IWH and IWI lines in G-2 generation. Information about number of sires and dams used to regenerate the flock in each generation is given in Table 44. So far, these two lines have undergone selection for higher egg production up to 64 weeks of age using Osborn index for two generations. At present evaluation of G-3 generation is under progress. Acceptable level of fertility and hatchability even at the end of first production cycle (Aprox. 72 weeks of age) is being maintained in these lines (Table 45).

Table 44. Effective population size and rate of inbreeding in IWH and IWI lines

Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
IWH line				
G-1	31	124	99.20	0.0050
G-2	50	114	139.02	0.0036
G-3	50	250	166.67	0.0030
Average	43.7	162.7	134.96	0.0039
Cumulative rate of inbreeding				0.0116
IWI line				
G-1	32	126	102.08	0.0049
G-2	50	250	166.67	0.0030
G-3	50	250	166.67	0.0030
Average	44	208.7	145.14	0.0036
Cumulative rate of inbreeding				0.0109

Table 45. Fertility and hatchability traits in IWH and IWI lines

Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
		FES	TES	
IWH line				
G-1	59.3	73.76	43.72	759
G-2	76.8	74.79	57.42	1365
G-3	76.4	71.36	54.54	2273
Average	70.8	73.30	51.89	
IWI line				
G-1	73.6	73.38	54.01	1541
G-2	74.2	75.07	55.75	2142
G-3	81.5	73.56	59.98	2057
Average	76.5	74.00	56.58	

FES: Fertile eggs set, TES: Total eggs set

Production traits: Performance of IWH and IWI lines with respect to various production traits is presented in Tables 46 and 47 respectively. Not much change was observed in age at sexual maturity during last four generations in both lines. However, egg production up to 52 or 64 weeks of age and egg mass at 64 weeks of age has consistently improved during last four generations with little or no change in egg weight at different age. Reduction in egg weight in G-3 generation could be attributed to reduction in body weight noticed in that generation in both lines.

Table 46. Production performance of IWH line up to G-3 generation at DPR, Hyderabad (Replaced line from CARI)

Generation	Body weight (g)				ASM (d)	Egg numbers			EM at 64 wks (g)	Egg weight (g)			
	16 wks	20 wks	40 wks	64 wks		40 wks	52 wks	64 wks		28 wks	40 wks	52 wks	64 wks
G-0	973	-	1420	-	141.9	106.6	148.3	181.8	11447	47.8	52.9	53.7	
G-1	979	-	1447	1506	142.6	107.8	166.6	230.1	12631	-	52.4	53.6	54.9
G-2	1054	1134	1527	1586	146.0	107.8	176.8	237.8	13091	46.3	52.4	-	55.2
G-3	783	1060	1326	-	140.7	117.9	188.8	-	-	43.9	48.1	51.4	-

Table 47. Production performance of IWI line up to G-3 generation at DPR, Hyderabad (Replaced line from CARI)

Generation	Body weight (g)				ASM (d)	Egg numbers			EM at 64 wks (g)	Egg weight (g)			
	16 wks	20 wks	40 wks	64 wks		40 wks	52 wks	64 wks		28 wks	40 wks	52 wks	64 wks
G-0	947	-	1472	-	142.2	105.5	153.7	191.1	11930	48.1	53.1	53.5	-
G-1	958	-	1405	1447	144.6	109.8	166.8	225.2	12567	-	52.9	53.6	55.8
G-2	1031	1100	1411	1474	149.3	106.3	174.5	234.1	13019	46.8	52.8	-	55.7
G-3	760	1043	1308	-	145.0	114.4	176.0	-	-	44.6	48..8	51.9	-

Note: *ASM: Age at sexual maturity, wt: weight, wks: weeks, EM: Egg mass*

11. Native Chicken Germplasm

A. PD-4 (Improved Aseel)

Origin

PD-4 variety evolved from Aseel (Peela) breed of chicken that was procured from Anand Agricultural University, Anand in the year 2006. Fertile eggs procured were set for incubation at experimental hatchery (PDP) and 196 good chicks of Aseel were hatched in two hatches in the first generation (G-1 generation) in the month of October 2006. Random mating using pooled semen was carried out to generate G-2 and G-3 generations. First pedigreed (S-1) generation was produced by mating 28 sires with 83 dams. S-2 generation was reproduced using Avian Leucosis Virus (ALV) negative 47 sires mated to 141 dams in two hatches. Subsequent generations were also regenerated using ALV negative sires and dams.

A pair of PD-4 birds

Effective population size and rate of inbreeding

The information on number of sires and dams used to reproduce each generation, effective population size and rate of inbreeding in PD-4 variety is presented in Table 48. Number of sires and dams used to regenerate this stock averaged over the generations were 49 and 118.8 respectively. Effective population size averaged over the years was 132.9 but it has increased from 83.7 (S-0 generation) to 150 (S-5 generation). Cumulative rate of inbreeding was 0.0198 and average rate of inbreeding was 0.0040 over 5 generations.

Fertility and Hatchability

The data on fertility and hatchability and number of chicks hatched in PD-4 variety are presented in Table 49. There was no significant change in fertility over generations (Y= (-0.77x +85.6)]. Highest fertility recorded was 88.1% (G-2 generation) and lowest was 77.3% (G-3 generation) while average fertility recorded was 82.5%. Similarly, there was no significant change in hatchability on FES [Y= (-0.8x+78.9)]. Highest and lowest hatchability recorded on FES was 81.2% (S-1 generation) and 70.7% (S-5 generation) respectively with average of 75.6%. There was no significant change in hatchability on total egg set [Y= (-0.80x+65.1)]. Highest and lowest hatchability on TES were 70.7% (S-1 generation) and 57.0% (S-5 generation) respectively while average hatchability was 61.9%.

Table 48. Effective population size and rate of inbreeding of PD-4 variety

Year	Generation	No. of Sires	No. of Dams	Effective population size (Ne)	Rate of inbreeding (ΔF)
2006-07	G-1	Random mating with pooled semen			
2007-08	G-2	Random mating with pooled semen			
2008-09	G-3	Random mating with pooled semen			
2009-10	S-1	28	83	83.7	0.0060
2010-11	S-2	47	141	141	0.0035
2011-12	S-3	70	70	140	0.0031
2012-13	S-4	50	150	150	0.0033
2013-14	S-5	50	150	150	0.0033
Average		49	118.8	132.9	0.0040
Cumulative rate of inbreeding					0.0198

Table 49. Fertility and hatchability traits of PD-4 variety

Year	Generation	Fertility (%)	Hatchability (%)		No of chicks hatched
			FES	TES	
2006-07	G-1	-	-	-	196
2007-08	G-2	88.1	75.1	62.3	269
2008-09	G-3	77.3	75.1	57.6	295
2009-10	S-1	87.0	81.2	70.7	840
2010-11	S-2	82.9	78.4	65.0	773
2011-12	S-3	80.9	76.0	61.4	817
2012-13	S-4	80.7	73.1	59.0	769
2013-14	S-5	80.7	70.7	57.0	881
Average		82.5	75.6	61.9	-

FES: Fertile eggs set, TES: Total eggs set

Growth and production traits

The data on the growth and production performance of PD-4 variety over generations is presented in Table 50. There was an improvement in body weight at 8 weeks of age from 445.1 to 461 g recorded in S-5 generation. The primary trait of selection for this variety was body weight at 16 weeks of age up to S-3 generation. Subsequently, selection criterion was changed selection for higher body weight at 8 weeks of age (S-4 generation onwards). Body weight at six weeks of age recorded in G-1, G-2 and S-1 generations were 305, 267 and 268 g respectively. There was an improvement (non-significant) of 142 g in body weight recorded at 16 weeks of age from 1052 (G-3) to 1194 g (S-5) [Y= (17.7x+1067)]. There was also an improvement of 368 g in body weight (non-significant) recorded at 24 weeks of age from 1303 (G-3) to 1671 g (S-5) [Y= (52.7x+1364)] although there was not much change in body weight recorded at 40 weeks of age over the generations. Egg production up to 40 weeks of age has improved from 31.3 to 52 numbers with highest egg production being 73.3 recorded in S-2 generation [Y= (4.7x+29.2)]. Egg weight at 40 weeks of age was maintained between 47 and 48 g over the generations [Y= (0.005x+47.4)]. Age at sexual maturity was in the range of 162 to 168.6 days [Y= (-1.3x+177.6)] with highest being 202 recorded in G-2 generation.

Genetic parameters

S-4 generation: Heritability estimates of body weight recorded at 8 and 16 weeks of age on combined sex were higher (0.57±0.20 and 0.42±0.19 respectively) while those of shank length were moderate to higher (0.43±0.17 and 0.24±0.15 respectively on sire component of variance. Heritability estimates of body weight of female birds at 24 and 40 weeks of age were 0.55±0.12 and 0.15±0.33 while those of shank length at respective age were 0.37±0.12 and 0.57±0.32 respectively on sire+dam component of variance. Heritability estimate of egg production up to 40 weeks of age was moderate (0.32±0.28) on sire+dam component of variance.

S-3 generation: Heritability estimates of body weight recorded at 0 day of age was very high (0.77±0.12) and those of 8 and 16 weeks of age on combined sex were high to low (0.40±0.06 and 0.11±0.02 respectively) while those of shank length were moderate to low (0.32±0.05 and 0.12±0.02 respectively) on sire+dam component of variance. Heritability estimates of egg weight at 32, 36 and 40 weeks of age were moderate to high (0.27±0.05, 0.26±0.05 and 0.46±0.09 respectively) while that of age at sexual maturity was high (0.41±0.08) on sire+dam component of variance.

S-2 generation: Heritability estimates of body weight and shank length recorded on combined sex at 16 weeks of age were on lower side (0.14±0.11 and 0.07±0.09 respectively) on sire component of variance.

S-1 generation: Heritability estimates of body weight recorded on combined sex at 4, 6 and 16 weeks of age were 0.37 ± 0.22, 0.42 ± 0.18 and 0.28 ± 0.12 respectively while those of shank length recorded at 6 and 16 weeks of age were 0.16 ± 0.12 and 0.18± 0.10 respectively on sire component of variance (Haunshi et al., 2011).

Table 50. Performance of PD-4 variety with respect to various economic traits

Year	Generation	Body weight (g)*		SL at 16* wks (mm)	Body weight (g)		SL (mm) 40 wks	ASM (d)	Egg weight (g)			EN to 40 wks
		8 wks	16 wks		24 wks	40 wks			28 wks	32 wks	40 wks	
2006-07	G-1	-	-	-	-	1805		164.0	39.6	41.3	46.5	31.3
2007-08	G-2	-	-	-	-	1853		162.0	39.6	41.2	48.1	33.6
2008-09	G-3/S-0	-	1052	-	1303	1832	102	213.3	42.7	45.8	48.6	36.2
2009-10	S-1	-	1112	108.2	1502	1850	106	174.0	42.6	44.6	47.6	59.5
2010-11	S-2	445.1	1157	108.1	1676	1887	106.3	162.8	43.7	-	47.3	73.3
2011-12	S-3	456.7	1188	110.5	1617	1987	106.4	162.3	-	44.3	47.1	52.0
2012-13	S-4	428.4	1071	106.1	1524	1835	105.7	168.6	41.6	43.3	48.1	51.0
2013-14	S-5	461.2	1197	106.9	1671	1913	105.0	162.3	40.9	44.5	47.6	59.7

Note: *SL: Shank length, ASM: Age at sexual maturity, EN: Egg number, Wks: weeks, *Pooled sex*

B. (PD-5) Kadaknath

PD-5 birds derived from Kadaknath breed of native chicken were procured from Anand Agricultural University (AAU), Anand in the year 2006. Initially 388 good chicks were hatched from fertile eggs procured from AAU, Anand in the first generation in the month of October 2006. Random mating using pooled semen was carried out to generate G-2 and G-3 generations. S-1 generation was produced using 42 sires and 125 dams in pedigreed mating while S-2 generation was reproduced using 17 sires and 20 dams that were tested Avian Leukosis virus (ALV) negative. From this generation onwards breeding of PD-5 line was discontinued and entire population was disposed off in the year 2011-12 due to the higher incidence of ALV infection in this line despite regenerating using ALV negative parents.

A pair of (PD-5) Kadaknath birds

Fertility and Hatchability

The data on fertility and hatchability and number of chicks hatched in PD-5 (Kadaknath) birds are presented in Table 51. The average fertility was 82.7% with highest fertility recorded was 85.1% (S-1 generation). Average hatchability on FES and TES was 90.8 and 73.1% respectively with highest hatchability recorded on FES and TES was 90.8% (S-2 generation) and 77.9% (S-1 generation) respectively. PD-5 birds seem to have comparatively better fertility and hatchability status as compared to PD-4 (Improved Aseel) variety.

Growth and production traits

The data on the growth and production performance of PD-5 birds over few generations is presented in Table 52. Body weight recorded at 4 weeks of age was 129.6, 114.6 and 121 g while that recorded at 6 weeks of age was 192, 193 and 203 g respectively in G-1, G-3 and S-1 generations. Body weight recorded at 8 weeks of age was 236 g in (S-1 generation). Shank length recorded at 16 weeks of age was 90.5 and 89.5 mm respectively in S-1 and S-2 generations. There was improvement in egg production up to 40 weeks of age as it went up to 62.4 (S-1) from 42.6 numbers (G-1) while egg weight at 40 weeks of age was maintained above 40.5 g.

Table 51. Fertility and hatchability traits of PD-5 (Kadaknath) breed

Year	Generation	Fertility (%)	Hatchability (%)		No. of Chicks Hatched
			FES	TES	
2006-07	G-1	-		-	388
2007-08	G-2	82.8	86.7	71.7	325
2008-09	G-3	82.3	83.0	69.2	463
2009-10	S-1	85.1	90.3	77.9	974
2010-11	S-2	80.4	90.8	73.1	473
Average		82.7	87.7	73.0	-

FES: Fertile eggs set, TES: Total eggs set

Table 52. Performance of PD-5 birds with respect to various economic traits

Year	Generation	Body weight (g)			ASM (d)	Egg weight (g)			EN to 40 wks
		16 wks*	24 wks	40 wks		28 wks	32 wks	40 wks	
2006-07	G-1	-	-	893	159.0	36.5	38.9	43.2	42.6
2007-08	G-2	-	-	1232	155.0	36.5	38.9	41.1	44.7
2008-09	G-3	619	937	1322	200.6	35.6	39.9	42.3	49.4
2009-10	S-1	681	1079	1474	181.0	36.0	37.1	41.6	62.4
2010-11	S-2	703	1009	1321	192.5	36.1	37.9	40.5	51.6

Note: *ASM: Age at sexual maturity, EN: Egg number, *Pooled sex*

C. Ghagus

The survey was carried out in the native tract of *Ghagus* breed of chicken (Bangarpet, Mulabagilu and Kolar taluks of Kolar district [Karnataka]) to explore the possibility of its availability. Four hundred and seventy eggs of Ghagus-ecotype chickens were procured from its native tract i.e. from Kolar district of Karnataka and a total of 287 good chicks were hatched and evaluated in G-0 generation. The data on fertility and hatchability are presented in Table 53. Initially the fertility of eggs collected from field was 80.49% but better fertility of 90.82% was observed subsequently with average fertility being 87.69%. The fertility of Ghagus seems to be one of the highest among native chicken breeds. Hatchability was also high as average hatchability on FES and TES were 88.72 and 77.89% respectively. G-1 and G-2 generations were generated using 150 dams inseminated with pooled semen from 50 sires. G-3 generation was produced by pedigreed random mating using 50 sire and 150 dams. Presently evaluation of G-3 generation of this breed is undergoing.

Table 53. Fertility and hatchability traits of Ghagus

Year	Generation	Fertility (%)	Hatchability (%)		No. of chicks hatched
			FES	TES	
2011-12	G-0	80.49	84.85	68.29	308
2012-13	G-1	88.96	90.17	80.21	807
2013-14	G-2	90.82	89.65	81.41	1117
2014-15	G-3	90.50	90.22	81.65	1255
Average		87.69	88.72	77.89	-

FES: Fertile eggs set, TES: Total eggs set


A pair of Ghagus birds

D. Nicobari fowl

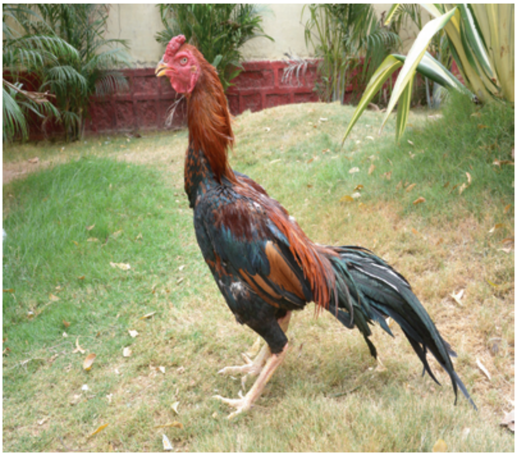
Fertile eggs of Nicobari fowl were procured from Central Agricultural Research Institute, Port Blair in the year of 2012. In first generation, a total of 52 chicks were hatched and evaluated for growth and production traits up to 60 weeks of age. In subsequent (G-1) generation a total of 444 good chicks were hatched with a fertility of 86.06% and hatchability on total egg set and fertile egg set basis were 80.10 and 93.06%, respectively by random mating using pooled semen. Currently two varieties such as Brown and Black Nicobari fowls are being maintained.


A pair of Nicobari Birds (Brown variety)

A pair of Nicobari birds (Black variety)

E. Aseel

Recently an effort was made to collect Aseel birds from field (native tract) for conservation and characterization purpose. A total of 344 fertile eggs of Aseel birds were collected from the farmers of Bhimavaram (West Godavari district of Andhra Pradesh), Shankarapally (Ranga Reddy district) and Patancheru (Medak district) villages of Telangana. A total of 171 good chicks were hatched and reared in first generation. Aseel birds originated from field seem to be susceptible to Marek's disease as mortality due to natural incidence of M.D. was very high in these birds. These birds are being maintained in semi-intensive system at the Directorate for further characterization.



A Rooster of Aseel breed at the Institute farm

12. Commercial Germplasm of Directorate of Poultry Research

Directorate of poultry research over period of its existence has evolved five commercial stocks for different types and proposes of poultry farming namely Vanaraja, Gramapriya, Srinidhi, Krishibro, Krishilayer, Swetasree, etc.

A. Vanaraja

Vanaraja is a dual purpose bird developed for low input poultry farming by crossing PD-1 (Sire line-Male parent) with PD-2 line (Dam line-Female parent). Adult birds of this cross are characterized by multicolour plumage ranging from black to full brown plumage with different intermediate colour combination shades. Barring, lacing, Columbian pattern on brown or tan background are also seen. (Ayyagari, 2001). This cross lays brown eggs.

A Male Vanaraja Bird

Production Performance

Vanaraja chicks attain 650-750 g body weight by six weeks of age and 2000-2200 g at the time of maturity. Birds start laying eggs at 175-180 days of age and lay about 110 eggs in 1.5 years of age. Their eggs weigh about 48-50 g at 28 weeks of age and 52 to 58 g at 40 weeks of age (Source: Vanaraja leaflet, PDP, Hyderabad).

Origin

The origin of Vanaraja has started with a chance observation that the performance of birds supplied to a Research Station of the Andhra Pradesh Agricultural University at Chintapalli, located in a high altitude and tribal area zone under integrated poultry-fish-rice farming system was perceived to be exceedingly better and became popular among the tribals. Therefore the research station repeated the order for supply of these birds in large number in subsequent year as well. The bird supplied was random bred multicoloured broiler control population. The feedback on their performance showed that these birds layed eggs even after 40 weeks of age and their eggs were hatched by broody hens and the chicks survived better; and their multi coloured plumage patterns were liked and accepted well by the tribals in the area (Ayyagri, 2001). Thus began the journey of development of Vanarja, the popular bird for backyard farming. Therefore, the random bred meat control population maintained under AICRP on poultry breeding at Project Directorate of Poultry was identified as suitable for developing a female parent line of Vanaraja as it was constituted from several coloured meat populations in the base generation and hence they had multicoloured plumage and their production performance was known through published work..

The red Cornish population that were moderately selected and discontinued from the AICRP on Poultry Breeding was considered appropriate for developing into a sire line population (Male parent line of Vanarja) as they would improve the weight gain and conformation of the terminal cross (Vanarja) during their juvenile growth and would generate income from the sale of surplus male birds in the backyard system (Ayyagari, 2001). Accordingly the Cornish population available at Odisha University of Agriclture and Technology (OUAT), Bhubaneshwar was chosen for this purpose and hatching eggs of this breed was procured. In initial generation all surviving male and females were used as parents in the base generation and pedigreed population were reproduced.

Cross thus produced using coloured meat control population and red Cornish was initially referred to as coloured germplasm and chicks of this cross were regularly supplied to farmers, private entrepreneurs, Govt. and NGO organizations as hatching eggs, day-old chicks and growing birds of 4 or 6 weeks of age. This cross was named as VANARAJA in the year 1997 and was exhibited with that catchy name in the 46th All India Livestock and Poultry show held in 1998 (Ayyagari, 2001). Since then it became very popular as an improved bird for backyard farming all over the country.

B. Gramapriya

Gramapriya is an egg type bird developed for backyard system of poultry farming by crossing PD-2 line (Sire line-male parent) with PD-3 line (Dam line-Female parent). Adult birds of this cross are characterized by dark brown to red coloured plumage with single comb and moderate size body weight. Gramapriya lay dark brown eggs with better size.

A Pair of Grampriya Birds

Production performance

Gramapriya chicks can attain body weight of 400-500 g by about six weeks of age and 1600-1800 at sexual maturity. They start laying eggs at 160-165 days of age and produce about 160-180 eggs in 72 weeks under farmers' backyard . Their egg weight was 49-52 g at 28 weeks of age and 57-58 g at 40 weeks of age (Source: Gramapriya leaflet, PDP, Hyderabad).

Origin

The development of this cross started with the purpose of meeting the requirement of the ICAR sponsored revolving fund hatchery unit of the Centre of Advanced Studies on Poultry Science of the Kerala Agricultural University (KAU), Mannuthy. Initially this cross was developed to ensure better egg production; better growth in cockerels and acceptable white plumage with coloured flecks for poultry production in rural areas of Kerala state and this cross was named as GRAMAPRIYA by the revolving fund scheme (Ayyagari, 2001). This cross was normally used to be known as WHITE GRAMAPRIYA at Project Directorate on Poultry, Hyderabad as these birds had white plumage with coloured flecks. However, this is now being called as *Swetasree*. This cross was developed by crossing random bred coloured meat control population as sire line with available White leghorn layers which were undergoing selection for increased egg production (as female line) in the year 1998 as the first consignment of hatching eggs was sent in March 1998 to KAU, Mannuthy.

Huge success of this cross as seen in Kerala due to better production and moderate growth lead to a conscious effort to develop the present day GRAMAPRIYA by crossing PD-2 line (Vanaraja female line) as sire line with PD-3 (Dahlem Red) line as female line to produce attractive red to dark brown coloured progenies instead of white plumage progenies by replacing White Leghorn layer with PD-3 line as female line. The brown coloured GRAMAPRIYA birds are being supplied though out the country as egg type bird for backyard system of production. However, now a separate male line is being developed from PD-2 line as a Gramapariya male line (GML) by selecting for higher shank length at six weeks of age. Therefore, presently GRAMAPRIYA cross is being produced by crossing GML as sire line with PD-3 (Dahlem Red) line as female line.

C. Srinidhi

Srinidhi is a meat type or dual purpose cross developed for backyard system of poultry farming by crossing control broiler (Sire line-Male parent) with PD-3 (Dam line-Female parent). Adult birds of this cross are characterized by multicoloured coloured plumage with barring feature and long shanks. Srinidhi birds lay brown shelled eggs.

Origin

The development of Srinidhi cross started in the year of 2010-11 and culminated by its release during silver jubilee celebrations of Project Directorate on Poultry by Honourable DDG (Animal Science) Dr. K.M.L. Pathak in March 2013. This germplasm is being supplied to various agencies throughout the country.

Production performance

Srinidhi birds can attain body weight of 600-650 g at field conditions by about six weeks of age. They weigh about 1900-2100 g at farm and 1700-2000 g at field condition at 20 weeks of age. They start laying eggs by 150-155 days at farm and 165-170 days at field conditions. Their annual egg production is 220-230 eggs at farm and 140-150 eggs at field conditions. Their egg weight is 50-51 g at farm and 48-50 g at field conditions Egg weight at 40 weeks of age is 54-55 and 52-55 g respectively at farm and field conditions. Their survivability is 98% in farm and 95% in field conditions (Source: Srinidhi leaflet, PDP, Hyderabad).

A Pair of Srinidhi Birds

D. Krishibro

Krishibro is the multi-coloured broiler that is produced by crossing PB-1 as sire line (Male parent) and PB-2 as dam line (Female parent).

A Male Krishibro Bird

Growth performance

Krishibro coloured broiler can attain body weight of 1500 g in 42 days of age with feed conversion ratio of 2.0. Dressing percentage of this cross will be about 70%. Mortality 3.0% up to 42 days of age. It has ranked third among 9 broiler crosses participated in the 24th Random Sample Poultry Performance Test (RSPPT) held at Gurgaon during the year 2005.

E. Krishilayer

It is a commercial layer variety that was evolved by crossing IWH as sire line (Male parent) and IWI line as dam line (Female parent) that are being subjected to genetic selection for higher egg production up to 64 weeks of age. This layer cross has the potential to produce about 280 eggs/year on hen housed basis.

A Krishilayer Hen

F. Swetasree

It is a layer cross (Earlier known as White Gramapriya) that is produced by crossing PD-2 line (VFL) as sire line (Male parent) with White Leghorn (IWI line) as dam line (Female parent) . This cross has white plumage with brown/black spots (flecks). As mentioned earlier it has a good demand in Kerala state for small scale intensive and rural poultry production. This cross has the potential to lay close to 200 eggs under scavenging conditions.

A Pair of Swetasree Birds

13. List of Research Projects in Breeding

In this chapter list of research projects under taken along with their Principal Investigators (PI) and period during which projects executed (1995-2015) is presented.

Year: 2010-2015

S. No.	Project Title	PI	Period
1	Development and improvement of male lines for dual purpose germplasm for backyard farming	Dr. M. K. Padhi Dr. U. Rajkumar	April 2010-Nov. 2014 Dec. 2014-Mar. 2015
2	Development, improvement and evaluation of female lines for backyard/free range farming	Dr. M. Niranjan	2010-2015
3	Maintenance and evaluation of native germplasm of chicken	Dr. Santosh Haunshi	2010-2015
4	Development of male line for production of egg type rural poultry	Dr. U. Rajkumar	2010-2015
5	Maintenance of elite layer germplasm evolved by various AICRP centres	Dr. R. N. Chatterjee Dr. M. K. Padhi Dr. Santosh Haunshi	01-04-2010 to 17-11-2013 18-11-2013 to 23-11-2014 24-11-2014 to 31-03-2015
6	Genetic characterization and improvement of a synthetic coloured broiler female line for various economic traits	Dr. K.S. Rajaravindra	2009-2014
7	Maintenance of coloured broiler population for development of climate resilient broilers	Dr. B. L. N. Reddy	2012-2015

Year: 2007-2012

Sl. No.	Project Title	PI	Period
1	Development of germplasm for backyard /free range farming for rural and tribal areas	Dr. M. Niranjan	2007-2010
2	Maintenance and evaluation of coloured broiler population	Dr. B.L.N. Reddy	2007-2009
3	Maintenance and evaluation of layer population	Dr. R.N. Chatterjee	2007-2010
4	Maintenance and evaluation of gene lines	Dr. B.L.N. Reddy Dr. U. Rajkumar	2007-08, 2008-09 to 2010-2011
5.	Improvement of synthetic coloured broiler male line and maintenance and evaluation of random bred broiler control population	Dr. B.L N. Reddy	2009-2012

Year: 2006- 2007

Sl. No.	Project Title	PI	Period
1	Genetic characterisation, development and improvement of dual purpose germplasm for backyard/ free range farming for rural and tribal areas	Dr. M. Niranjan	2006-07
2	Genetic characterisation, evaluation and improvement of synthetic coloured broiler lines to optimize production efficiency at parent and broiler levels	Dr. B.L.N. Reddy	2006-07
3	Development, evaluation and genetic improvement of gene lines with tropical adaptable major genes for utilization in tropical poultry production	Dr. B.L.N. Reddy	2006-07
4	Improvement of poultry for egg production	Dr. R.N. Chatterjee	2006-07

Year: 2000- 2006

Research programmes	Project Title	PI	Period
Programme-I Development of germplasm for backyard/free range farming for rural and tribal areas	1. Development of male parent line for the production of suitable germplasm for backyard farming	Dr. N.K. Praharaj Dr. N.K. Praharaj / Dr. R.C. Hazary Dr. R.C. Hazary Dr. M. Niranjan	2000-01, 2001-02 2002-03 2003-04 2004-05, 2005-06
	2. Development of female parent line for the production of suitable germplasm for backyard farming	Dr. R.P. Sharma Dr. M. Niranjan	2000-01, 01-02, 02-03, 2003-04. 2004-05, 2005-06
	3. Improvement of Dahlem Red for development of a tinted egg layer for backyard poultry production	Dr. R.C. Hazary Dr. M. Niranjan	2000-01, 01-02, 02-03, 2003-04 2004-05, 2005-06

Programme-III Development of gene lines with single genes such as sex-linked recessive dwarf (dw) gene and naked neck gene and their utilization in tropical broiler production	1. Development, evaluation and regeneration of gene line with Naked neck (Na) gene to study their utility in tropical poultry production 2. Improvement of gene lines with single genes such as sex linked dwarf (dw) gene and their utilization in tropical broiler production	Dr. R.C. Hazary, Dr. B.L.N. Reddy Dr. N.K. Praharaj Dr. N.K. Praharaj/ Dr. R.C. Hazary Dr. R.C. Hazary Dr. B.L.N. Reddy	2000-01, 01-02, 02-03, 2003-04 2004-05, 2005-06 2000-01, 2001-02 2002-03 2003-04 2004-05, 2005-06
Programme-IV Pure line improvement of coloured broiler population to optimize production efficiency at parent and broiler level	1. Genetic characterization and improvement of coloured broiler female line with respect to economic traits 2. Genetic characterization and improvement of coloured broiler male line with respect to economic traits 3. Maintenance and evaluation of random bred control population for meat	Dr. R.P. Sharma Dr. B.L.N. Reddy Dr. N K. Praharaj Dr. N. K. Praharaj/ Dr. R.C. Hazary Dr. B.L.N. Reddy Dr. R.P. Sharma Dr. B.L.N. Reddy	2000-01, 01-02, 2002-03 2003-04, 04-05, 2005-06. 2000-01, 2001-02 2002-03 2003-04, 04-05, 2005-06 2000-01 01-02, 2002-03 2003-04, 04-05, 2005-06

Programme-V Pure line improvement of layer populations for specific objectives	1. Genetic improvement and evaluation of pure line germplasm of layer populations	Dr. D. Chaudhuri Dr. A.K. Panda Dr. R.N. Chatterjee	2000-01, 01-02, 02-03, 2003-04 2004-05 2005-06
	2. Maintenance and evaluation of random bred control population for egg	Dr. R.C. Hazary Dr. A. K. Panda Dr. R.N. Chatterjee	2000-01, 01-02, 02-03, 2003-04 2004-05 2005-06
	3. Evaluation and investigation of strain cross performance of White Leghorn layers	Dr. R.C. Hazary Dr. A.K. Panda Dr. R.N. Chatterjee	2000-01, 01-02, 02-03, 2003-04 2004-05 2005-06
	4. Evaluation and selection for efficiency of feed utilization in egg type chicken	Dr. R. C. Hazary Dr. A.K. Panda Dr. R.N. Chatterjee	2000-01, 01-02, 02-03, 2003-04 2004-05 2005-06

Year: 1999-00

Sl. No.	Research Programmes	Project Title	PI	Period
I	Development of germplasm and low cost inputs for rural poultry production	1. Development of a suitable male parent line for the backyard farming	Dr. N.K. Praharaj	1999-00
		2. Development of female parent line for the backyard farming	Dr. R.P. Sharma	1999-00
		3. Improvement of Dahlem Red for development of a tinted egg layer for backyard poultry production	Dr. R.C. Hazary	1999-00
		4. Evaluation and improvement of a tinted egg layer for various economic traits	Dr. S.K. Mishra	1999-00
II	Development of gene lines with single genes such as sex-linked recessive dwarf (dw) gene and naked neck gene and their utilization in tropical broiler production	1. Development, evaluation and regeneration of gene line with Naked neck (Na) gene	Dr. S.K. Mishra	1999-00
		2. Development, evaluation and regeneration of gene line with sex linked dwarf gene	Dr. N.K. Praharaj	1999-00

III	Pure line improvement of coloured broiler population to optimize production efficiency at parent and broiler level	1. Pure line improvement of coloured broiler population to optimize production efficiency at parent and broiler level.	Dr. N.K. Praharaj	1999-00
		2. Genetic characterization and improvement of broiler female line with respect to economic traits	Dr. R.P. Sharma	1999-00
		3. Maintenance and evaluation of random bred control population for meat.	Dr. R.P. Sharma	1999-00
IV	Pure line improvement of layer populations for specific objectives	1. Genetic improvement and evaluation of pure line germplasm of layer populations.	Dr. D. Chaudhuri	1999-00
		2. Maintenance and evaluation of random bred control population for egg	Dr. R.C. Hazary	1999-00
		3. Evaluation and investigation of strain cross performance of White Leghhorn layers	Dr. R.C. Hazary	1999-00

Year: 1998-99

Sl. No.	Research Programme	Project Title	PI	Period
I	Pure line improvement of layer populations for specific objectives	1. Genetic improvement and evaluation of pure line germplasm of layer populations.	Dr. B.L.N. Reddy / Dr. A.K. Panda	1998-99
		2. Maintenance and evaluation of random bred control population for egg	Dr. B.L.N. Reddy / Dr. A K. Panda	1998-99
II	Pure line improvement of coloured broiler population to optimize production efficiency at parent and broiler level	1. Genetic characterization and improvement of broiler male and female lines with respect to economic traits.	Dr. N.K. Praharaj	1998-99
		2. Maintenance and evaluation of random bred control population for meat.	Dr. V. Ayyagari	1998-99

III	Development of gene lines with single genes such as sex-linked recessive dwarf (dw) gene and naked neck (Na) gene and their utilization in tropical broiler production	1. Development, evaluation and regeneration of gene lines with Naked neck (Na) and sex-linked recessive dwarf (dw) genes	Dr. V. Ayyagari	1998-99
IV	Development of germplasm for backyard/free range farming for rural and tribal areas	1. Development of a suitable male parent line for the backyard farming 2. Development of female parent line for the production of suitable germplasm for backyard farming	Dr. N.K. Praharaj Dr. V. Ayyagari	1998-99 1998-99

Year: 1995-1998

Sl. No.	Project Title	PI	Period
1.	Genetic improvement and evaluation of pure line germplasm of layer populations	Dr. B.L.N. Reddy	1997-98 1996-97 1995-96
2.	Genetic characterization and improvement of synthetic White Leghorn strain for economic traits	Dr. B.L.N. Reddy	1995-96
3.	Maintenance and evaluation of random bred control population for egg	Dr. B.L.N. Reddy	1997-98 1996-97 1995-96
4.	Genetic characterization and improvement of broiler male and female lines (Pb-1 and Pb-2) with respect to economic traits	Dr. N.K. Praharaj Dr. N.K. Praharaj Dr. S.K. Mishra	1997-98 1996-97 1995-96
5.	Maintenance and evaluation of random bred control population for meat	Dr. V. Ayyagari	1997-98 1996-97 1995-96
6.	Development of gene lines with single genes such as Naked neck (Na) and sex-linked recessive dwarf (dw) gene for using as source of single genes relevant for tropical poultry production	Dr. V. Ayyagari	1997-98 1996-97 1995-96
7.	Sire by protein interaction for growth, feed efficiency, and immune response in coloured broilers	Dr. N.K. Praharaj	1997-98 1996-97
8.	Comparative evaluation of commercial layer stocks developed in AICRP centres *vis a vis* the commercials from industry	Dr. S.V. Rama Rao	1996-97 1995-96

14. List of Publications in Breeding

1. Research articles

A. International

Chatterjee, R.N., Bhattacharya,T.K., Dange, M., Dushyanth, K., Niranjan, M., Reddy, B.L.N and Rajkumar, U. 2014. Genetic heterogeneity among various indigenous and other chicken populations with microsatellite markers. *Journal of Applied Animal Research,* 43(3): 266-271 Doi: 10.1080/09712119.2014.963097.

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Rajkumar, U., Reddy, B.L.N., Rajaravindra, K.S., Niranjan, M., Bhattacharya, T.K., Chatterjee, R. N., Panda, A. K., Reddy, M. R. and Sharma, R. P. 2010. Effect of Naked neck gene on immune competence, serum biochemical and carcass traits in chicken under tropical climate. *Asian Australasian Journal of Animal sciences,* 23: 867- 872.

Rajkumar, U., Sharma, R.P., Padhi, M.K., Rajaravindra, K.S., Reddy, B.L.N., Niranjan, M., Bhattacharya, T.K., Haunshi, S. and Chatterjee, R. N. 2011. Genetic analysis of juvenile growth and carcass traits in a full diallel mating in selected colored broiler lines, *Tropical Animal Health and Production* 43(6):1129-1136.

B. National

Chatterjee, R.N., Bhattacharya, T.K. Sharma, R.P., Dange, M. Reddy, B.L.N. and Rajkumar, U. 2010. Genetic analysis of Naked neck chicken. *Indian Veterinary Journal,* 87:1100-1103.

Chatterjee, R.N., Niranjan, M. Panda, A.K., Reddy, B.L.N., Bhanja, S.K. and Singh, D. 2008. Inheritance of important economic traits in 3 pure lines and a control population of White Leghorn, *Indian Journal of Animal Sciences*, 78: 75-79.

Chatterjee, R.N., Sharma, R.P., Niranjan, M., Reddy, B.L.N. and Mishra, A. 2006. Genetic studies on egg quality traits in different White Leghorn populations, *Indian Journal of Animal Genetics and Breeding*, 27: 51-54.

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Padhi, M.K. and Chatterjee, R.N. 2013. Carcass quality traits in four different crossbreds developed for backyard poultry and the effect of age on carcass quality under intensive system of rearing. *Indian Journal of Animal Sciences*, 83:1102-1108.

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Padhi, M.K., Rajkumar, U., Haunshi S., Niranjan, M., Panda, A.K., Bhattacharya, T.K., Reddy, M.R., Bhanja S.K. and Reddy, B.L.N. 2012. Comparative evaluation of male line of Vanaraja, Control broiler, Vanaraja commercial in respect to juvenile and carcass quality traits. *Indian Journal of Poultry Science*, 47 (2): 136-139.

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Praharaj, N.K., Sridevi, B., Reddy, M.R., Rama Rao, S.V. and Panda, A.K. 1999. Immune competence and disease resistance in broiler chicks as influence by genotypes and dietary energy level. *Indian Journal of Animal Sciences*, 69(9):657-661.

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Rajkumar, U., Rajaravindra, K.S., Reddy, B.L.N., Niranjan, M. Bhattacharya, T.K. and Chatterjee, R.N. 2012. Evaluation of crosses involving broiler dwarf dam lines. *Indian Veterinary Journal*, 89(12): 53-54.

Rajkumar, U., Rajaravindra, K.S., Haunshi, S. Niranjan, M., Bhattacharya, T.K. and Chatterjee, R.N. 2012. Genetic architecture of growth and production parameters in laying cycle of 72 weeks in naked neck chicken. *Indian Journal of Animal Sciences*, 82(6): 615-619.

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Rajkumar, U., Rajaravindra, K.S., Niranjan M., Reddy, B.L.N., Bhattacharya, T.K. and Chatterjee, R.N. and Sharma R.P. 2010. Evaluation of naked neck broiler genotypes under tropical environment. *Indian Journal of Animal Sciences*, 80: 463-467.

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Reddy, M.R., Panda, A.K., Praharaj, N.K. Rama Rao, S.V., Choudhary, D. and Sharma, R.P. 2002. Comparative evaluation of immune competence and disease resistance in dual purpose chicken *Vanaraja and Gramapriya vis a vis* coloured synthetic broiler. *Indian Journal of Animal Sciences*, 72: 6-8.

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5. Research abstracts presented in symposia/conferences

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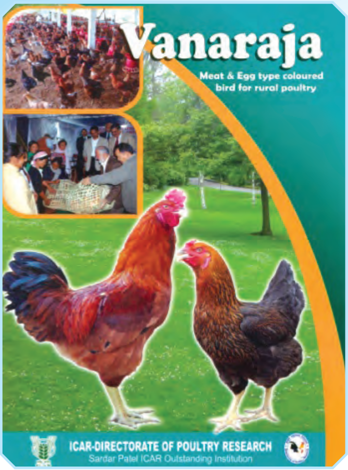
Vanaraja
Meat & Egg type coloured bird for rural poultry
ICAR-DIRECTORATE OF POULTRY RESEARCH
Sardar Patel ICAR Outstanding Institution


Gramapriya
A prolific brown egg layer
ICAR-DIRECTORATE OF POULTRY RESEARCH
Sardar Patel ICAR outstanding institution


Krishibro
A unique coloured broiler chicken
ICAR-DIRECTORATE OF POULTRY RESEARCH
Sardar Patel ICAR outstanding institution


Srinidhi
A rural variety for meat and egg purpose
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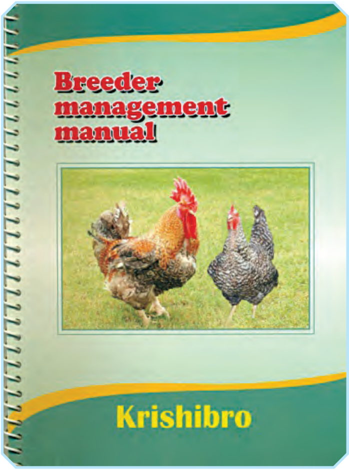
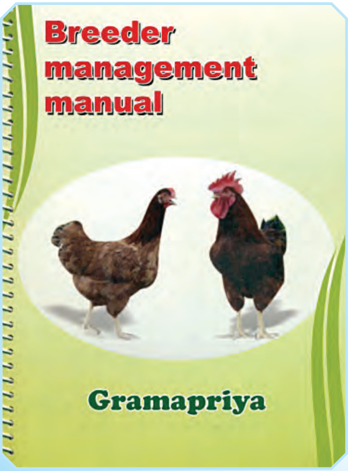
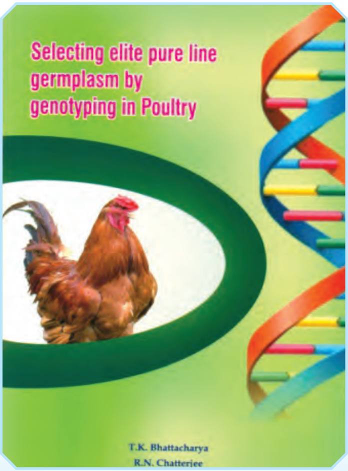
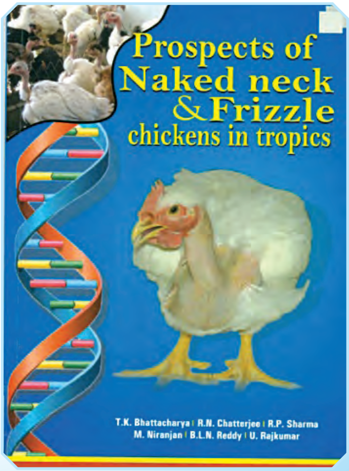
Sardar Patel ICAR outstanding institution


Breeder management manual
Vanaraja


Breeder management manual
Krishibro


Breeder management manual
Gramapriya


Selecting elite pure line germplasm by genotyping in Poultry
T.K. Bhattacharya
R.N. Chatterjee


Prospects of Naked neck & Frizzle chickens in tropics
T.K. Bhattacharya | R.N. Chatterjee | R.P. Sharma
M. Niranjan | B.L.N. Reddy | U. Rajkumar

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