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Short term selection response for higher 52 week egg mass based on Osborn index in *Vanaraja* female parent line chicken

U RAJKUMAR[1✉], M NIRANJAN[1], L L L PRINCE[1], S HAUNSHI[1], C PASWAN[1] and B L N REDDY[1]

ICAR-Directorate of Poultry Research, Hyderabad, Telangana 500 030 India

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ABSTRACT

Short term selection response for egg mass at 52 weeks of age (EM52), the primary trait of selection and the correlated response of other production traits was evaluated utilizing the last five generations data of Vanaraja female line (PD-2) at ICAR-Directorate of Poultry Research, Hyderabad. The phenotypic and genetic response for EM52 was significant with a magnitude of 341.9 and 237.4 g per generation, respectively. The correlated response of egg production at 52 weeks was also significant with 5.68 and 4.37 eggs per generation on genetic and phenotypic scale, respectively. The age at sexual maturity reduced over the generation in a desired direction. The least square means (LSMs) for production traits (EM52, EP52, EW52, EP 40 and ASM) varied significantly across the generations. The LSMs of EM52 (7898±2.01 g) and EP52 (138.60±0.03 eggs) were significantly higher in S-5 generation. Selection intensity (i) ranged from 0.44 to 1.10 and the rate of inbreeding was 0.003. Realized and estimated heritabilities of EM52 were 0.04 and 0.11, respectively. The significant improvement in primary trait and other important correlated traits indicated the effectiveness of Osborn index selection in PD-2 line, which will contribute to the improvement in egg production and egg weight in terminal cross Vanaraja chicken variety.

Keywords: Body weight, Egg mass, Egg production, Genetic response, Selection, Vanaraja

Rural poultry is one of the proven tools for alleviation of poverty and malnutrition in rural and tribal areas of the country. The quality germplasm with higher productivity and acceptability among the farmers is the key for enhancing the contribution of rural poultry, which has been the major hindrance for expansion of backyard poultry over the years. Vanaraja developed at ICAR- Directorate of Poultry Research is one of the widely accepted dual purpose chicken varieties across the country. Vanaraja terminal cross has been improved for higher productivity through continuous selection in parent lines.

Vanaraja female line (PD-2) has been under selection for higher 52 week egg mass (EM52), one of the important traits in chicken to maintain egg production, egg weight and other positively associated traits. The introduction of high yielding rural chicken varieties with high productivity in terms of growth and production would enable the farmers to get subsidiary income (Rajkumar *et al.* 2018, 2019). Osborn index is the widely used selection method for the improvement of egg production and egg mass in chicken. It is the single trait multi source information index selection employed for improving the low heritable traits which are governed by both additive and non additive gene actions. Response to selection depends on the initial population size, gene frequency, mutation, allelic fixation, random drift and physiological limits (Falconer and Mackay 1997).

Selection criteria of EM52 and its response over the generations needs to be evaluated for efficacy of selection method employed in the population. However, the studies with egg mass as selection criterion are limited in literature, more so with respect to rural poultry lines. Therefore, the present study on short term selection response for primary trait and correlated response for other associated traits was evaluated in PD-2 chicken.

MATERIALS AND METHODS

The experiment was conducted at experimental farm of ICAR-Directorate of Poultry Research, Hyderabad, Telangana, India. The experiment was approved by the Institute Animal Ethics Committee.

Experimental population: The data on PD-2 chicks produced from a pedigreed mating with 50 sires and 250 dams for five generations reared under standard management practices at ICAR-Directorate of Poultry Research were utilized in the present study. The sample size varied from 1826 (S-1) to 3037 (S-5) generation in chicks and 461 (S-2) to 781 (S-5) in adult female birds. PD-2 line was derived from a random bred control population (Ayyagari 2008). The population was under selection for higher egg production for 11 generations and higher egg mass for the last five generations. PD-2 is a female parent line of Vanaraja chicken variety. Rural control random bred population (RC) was utilized as control

Present address: [1]ICAR–Directorate of Poultry Research, Hyderabad, Telangana 500 030, India. ✉Corresponding author e-mail: ullengala@yahoo.com

population to estimate the genetic progress in the PD-2 line with 410–530 birds for juvenile traits and 112–135 hens for production traits in different generations. The RC population was evolved at ICAR-DPR, Hyderabad and maintained in a pedigreed random mating without any selection.

Management: Chicks were produced in 3 to 4 hatches in every generation; wing banded and kept on deep litter management under standard brooding, feeding and management practices in each generation uniformly. RC chicks were taken along with second hatch in every generation. The chicks were fed *ad lib.* with broiler starter ration (2900: ME, 22: CP) up to 6 weeks of age. The birds were maintained on a feed restriction schedule from 7th week onwards with grower ration (2800 Kcal: ME and 18%: CP) up to 16 weeks of age and breeder (2700 Kcal: ME, 16.50%: CP and Calcium: 3.5%) ration up to 52 weeks of age.

The data collected on growth and production traits over last five generations were utilized in the present study. The body weights at 4 (BW4), 6 (BW6), 20 (BW20), 40 (BW40) and 52 (BW52) weeks and shank length at 4 and 6 weeks of age were recorded. Age at sexual maturity (ASM), egg weights, egg production and egg mass at 40 (EW40, EP40 and EM40) and 52 (EW52, EP52 and EM52) weeks of age were recorded in every generation.

Statistical analysis: Data were analyzed using Least squares technique (Harvey 1990) with a computer package to study the effect of generation. Genetic and phenotypic responses were determined by regression of control deviated means and population means over the generations, respectively. The significance of regression coefficient was tested using SPSS 12.0. The hatch corrected data were utilized for estimating the heritability estimates in S-5 generation by variance component analysis (King and Henderson 1954). The hatch correction of the data was done with least square constants for each trait. The effective population size, selection intensity, rate of inbreeding, realized heritability were estimated by standard procedure (Falconer and Mackay 1997). The statistical model employed for analysis was as follows:

$$Y_{ijkl} = \mu + s_i + d_j + h_k + e_{ijkl}$$

where, Y_{ijkl}, lst observation on the progeny of the ith sire, jth dam and kth hatch; μ, overall population mean; s_i, effect of ith sire; d_j, effect of jth dam; h_k, kth hatch; e_{ijkl}, random error NID (0, σ^2e).

RESULTS AND DISCUSSION

The least squares means (LSMs) for body weights and shank length over five generations are presented in Table 1. The juvenile body weights (BW4 and BW6) gradually increased significantly (P≤0.05) from S-1 to S-5 generation. The generation had significant (P≤0.05) effect on shank lengths at 4 and 6 weeks of age (Table 1). The shank length (SL4 and SL6) gradually improved over the generations. Gradual improvement was observed in juvenile body weights and shank lengths over the generations indicating the presence of genetic variability in the population though selection was not aimed at growth traits. Similar increased response to growth traits was reported by Rajkumar *et al.* (2016) in short term selection experiment in PD-2 line and by Ogbu (2012) in Nigerian indigenous chicken. Healthy juvenile body weights are important for optimum body weight at laying and also for ASM which was clearly evident in the present study with significant reduction in ASM. The numerical reduction in BW4 and BW6 in last generation might be due to the variations in the management and environment conditions during the early phase. Long and strong shanks are important for rural varieties as birds with longer shanks run fast and escape from predators in the fields (Ayyagari 2008). The higher shank lengths in parent lines of terminal crosses contribute to higher shanks in the offsprings resulting in a bird with longer shanks which can run faster and escape from predators efficiently.

The correlation coefficients between BW4 and BW6, BW4 and SL4, BW4 and SL6, BW6 and SL6 were 0.91, 0.78, 0.77 and 0.94, respectively. The correlation between body weight and shank length were high with positive association. The positive significant association between body weight and shank length in chicken was well established fact as both are positively and highly correlated traits (Rajkumar *et al.* 2010, 2020a). Though the body weight and shank length were not included in selection in PD-2 line, but it plays an important role as optimum growth rate during juvenile stage which is essential for better growth and productivity during the laying stage. The

Table 1. Least squares mean for body weights (g) and shank length (mm) in PD-2 line chicken

Generation	n	Juvenile body weights, g		Shank length, mm		n	Adult body weight, g		
		BW4	BW6	SL4	SL6		BW20	BW40	BW52
S-1	1826	249.6±0.03^{b}	489.5±0.10^{bc}	50.21±0.001^{c}	66.76±0.001^{c}	479	1802±0.37^{bc}	2455±0.45	2732±0.61^{ab}
S-2	2479	254.8±0.01^{b}	477.6±0.08^{c}	52.33±0.003^{c}	67.35±0.001^{c}	461	1930±0.31^{b}	2514±0.45	2728±0.85^{ab}
S-3	1917	272.3±0.04^{ab}	545.1±0.09^{b}	52.18±0.002^{c}	66.79±0.001^{c}	620	2017±0.81^{b}	2431±0.35	2604±0.65^{b}
S-4	2917	335.6±0.01^{a}	662.4±0.02^{a}	54.21 ±0.001^{b}	71.53±0.002^{b}	608	2165±0.34^{a}	2551±0.42	2842±0.54^{a}
S-5	3037	325.7±0.02^{a}	614.51±0.03^{a}	56.10±0.001^{a}	73.53±0.001^{a}	781	1856±0.25^{b}	2475±0.34	2728±0.44^{ab}

Different superscripts with in the column differ significantly at P≥0.05. BW4, Body weight at 4 weeks; BW6, Body weight at 6 weeks; BW20, Body weight at 20 weeks; BW40, Body weight at 40 week; BW52, Body weight at 52 weeks; SL4, Shank length at 4 weeks; SL6, Shank length at 6 weeks.

Table 2. Least squares means for production traits in PD-2 line over the last five generations

Generation	n	ASM, d	Egg weight, g		Egg production nos.		Egg mass, g	
			EW40	EW52	EP40	EP52	EM40	EM 52
S-1	479	172.9±0.08[a]	52.65±0.003	53.20±0.007[b]	77.61±0.13[c]	121.47±0.02[d]	4123±2.31	6462±5.70[d]
S-2	461	161.59±0.03[b]	52.68±0.006	52.04±0.007[b]	85.18±0.02[a]	123.71±0.06[cd]	4487±1.91	6437±3.55[d]
S-3	620	160.10±0.56[bc]	51.45±0.11	53.87±0.84[b]	76.99±1.24[c]	126.26±1.41[c]	4363±1.47	6821±1.21[c]
S-4	608	157.01±0.01[cd]	52.64± 0.005	56.00± 0.006[a]	80.29±0.03[b]	133.16± 0.05[b]	4218±2.10	7447 ± 2.98[b]
S-5	781	159.15±0.06[c]	52.91±0.005	55.75±0.005[a]	84.72±0.02[a]	138.60±0.03[a]	4477±1.31	7898±2.01[a]

Different superscripts with in the column differ significantly at P≥0.05. ASM, Age at sexual maturity; EW40, Egg weight at 40 weeks; EW52, Egg weight at 52 weeks; EP40, Egg production at 40 weeks; EP52, Egg production at 52 weeks; EM52, Egg mass at 52 weeks of age.

phenotypic correlations also followed a similar trend.

The adult body weights, BW20 and BW52 differed significantly (P≤0.05) across the generations. The BW20 was maintained between 1,800–2,000 g, the ideal body weight at laying to maintain the egg production during the laying phase in all the generations except in S-5 generation. The body weights obtained at different ages do not reflect the actual potential of the birds as the birds were on restricted feeding schedule to maintain the body weight at laying for realizing optimum egg production.

The LSMs for production traits are presented in Table 2. The LSMs for production traits varied significantly across the generation except EW40 and EM40. The EM52, the primary trait of selection was improved from 6462±5.70 g in S-1 to 7898±2.01 g in S-5 generation. The EM52 was 6324±125, 5920±141, 6031±129, 5998±147, 6851±136 g in rural control population in five generations (S-1 to S-5), respectively. The EM40 was higher in S-2 generation and reduced till S-4 and increased in S-5 generation without any clear trend. However the variations were not significant (P≤0.05) across the generations. The differences in egg mass might be due to the variations in egg weights and egg number recorded in respective generations which could be due to the feeding and management conditions followed (Rajkumar *et al.* 2020b). The egg production (EP40 and EP52) showed significant (P≤0.05) increasing trend over the generations. Egg production and egg mass are positively associated traits with high degree of correlation leading to improvement in egg production as correlated response to selection. Selection for egg number improved the egg mass as correlated response due to high positive genetic and phenotypic correlations between the traits (Younis *et al.* 2014, El Attrouny *et al.* 2019). The EP52 and EW52 increased gradually as a correlated response to the selection as EM52 is the product of egg production and egg weight. The EW40 and EM40 increased without any specific trend as a correlated response to the selection for EM52. ASM gradually reduced over the generations in positive direction as correlated response to selection. Similar reduction in ASM was reported in Dokki 4 chicken (Younis *et al.* 2014) and in Benha chickens (El Attrouny *et al.* 2019) from Egypt. Reddy *et al.* (2004) observed reduction in ASM and egg weight as correlated response to selection for egg number similar to the present findings as ASM and egg number are negatively correlated traits. The egg mass selected lines matured later and laid heavier eggs with maintaining the optimum egg production (Venkataramaiah *et al.* 1986) in layer lines. However, in the present study the egg weight improved as the selection criterion was egg mass which might have influenced both egg number and egg weight.

Genetic and phenotypic correlations between production traits are presented in Table 3. The ASM and egg weights (EW40 and EW52) had positive correlation coefficients revealing that the birds matured early laid smaller eggs. The EW40 and EW52 had highly positive correlation. The EP40 was negatively associated with ASM and egg weights at different ages (Table 3). The egg mass and ASM had negative or lowly magnitude positive association. Egg mass and egg weights had high magnitude positive correlations as larger eggs contributed more to the egg mass. The egg mass and egg production had a positive association. The association between egg productions with all other traits was in accordance with the earlier studies in various chicken populations (Jilani *et al.* 2007, Rajkumar *et al.* 2020a; b).

The direct and correlated response for production traits, realized and estimated heritability estimates are presented in Table 4. The phenotypic and genetic response of EM52, the primary trait of selection was positive and significant indicating the effectiveness of selection based on Osborn

Table 3. Genetic (above the diagonal) and phenotypic (below) correlation coefficients for production traits in PD-2 line

Trait	ASM	EW40	EW 52	EP40	EP52	EM40	EM52
ASM	*	0.40	0.57	-0.35	-0.18	0.09	-0.21
EW40	0.33	*	0.91	-.0.81	-0.39	0.74	0.49
EW52	0.29	0.67	*	0.45	0.87	0.28	0.86
EP40	-0.19	-0.56	0.01	*		0.71	0.69
EP52	-0.08	-0.23	-0.45	0.58	*		0.88
EM40	0.02	0.71	0.21	0.39	0.31	*	0.92
EM52	0.11	0.51	0.72	0.33	0.79	0.81	*

ASM, Age at sexual maturity; EW40, Egg weight at 40 weeks of age; EW52, Egg weight at 52 weeks of age; EP40, Egg production at 40 weeks of age; EP52, Egg production at 52 weeks of age; EM40, Egg mass at 40 weeks of age; EM52, Egg mass at 52 weeks of age.

Table 4. Direct and correlated response for production traits in each generation in PD-2 line

Parameter	Genetic response	Phenotypic response	Realized heritability	Estimated heritability
Direct response				
EM 52, g (primary trait)	237.4*	341.9*	0.04	0.11±0.10
Correlated response				
EP52, no	5.68*	4.37*	0.05	0.10±0.07
EM40, g	62.60	44.90	0.02	0.07±0.06
EP40, no	2.34	0.93	0.04	0.06±0.08
EW52, g	0.14	0.91	0.14	0.34±0.11
EW40, g	0.08	0.05	0.11	0.40±0.13
ASM, d	–1.08	–3.21	0.05	0.18±0.09

Significant at P≥0.05; EM52, Egg mass at 52 weeks; EP52, Egg production at 52 weeks; EM40, Egg mass at 40 weeks; EP40, Egg production at 40 weeks; EW52, Egg weight at 52 weeks; EW40, Egg weight at 40 weeks; ASM, Age at sexual maturity.

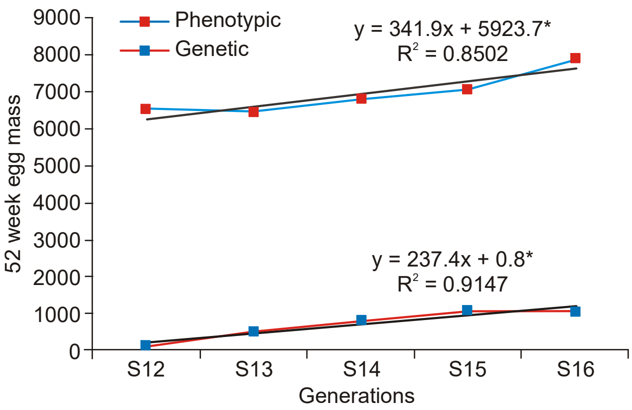

Fig. 1. Direct genetic and phenotypic response for primary trait, EM52 in PD-2 line.

index (Fig.1). The phenotypic and genetic response for EM52 was 341.9 and 237.4 g per generation. The correlated response for ASM was in positive direction with considerable reduction over the generations. The genetic and phenotypic correlated response for EP52 was significant in positive direction while EM40, EP40, EW40 and EW52 showed increasing trend over the generations. The underlying genetic theory in any selection experiment has been the response for a quantitative trait would continue only if additive genetic variation remains in the population or if spontaneous mutations occurs that influence the performance of the trait under selection (Dickerson 1955, Falconer and Mackay 1997) and also due to epistasis and gene interaction that influence the phenotypic expression (Dunnington *et al.* 2013). In short term selection experiment of few generations, the response to selection is primarily a function of the alleles segregating in the base population (Fuller *et al.* 2005). The significant positive response for EM52 in our study might be due to the ideal breeding program, large effective population size and the pleiotropic effects of the loci controlling egg weight and egg production. The genetic and phenotypic responses for egg numbers similar to the present findings were reported in Rhode Island chicken from Nigeria (Nwagu *et al.* 2007). The continuous positive response over the generations might be due to the presence of genetic variability and network of interacting loci for the primary trait at the beginning of the breeding plan (Pettersson *et al.* 2011, Dunnigton *et al.* 2013) and continue to be present after five generations of selection leading to the improved performance. The correlated response in associated traits in chicken was a well-established (Rajkumar *et al.* 2020c; d, Prince *et al.* 2020) phenomena which resulted in faster genetic progress in more number of traits at a time.

The realized heritability is the degree to which a particular trait expected to be improved by selection. The realized h^2 estimates were lower than the estimated ones and correlated traits (EM40, EP40 and EP52) were low in magnitude. The realized heritability is a function of linear regression of response over the generations which could only be an approximation as the response was never linear (Pinard *et al.* 1992) in a population. The lower realized and estimated heritability for primary trait and other correlated traits might be due to the selection for the last five generations which tends to decrease the variability and increase the homozygosity in the population. Another possible reason for low heritability estimates might be the low heritable nature of the production traits especially egg production and egg mass. Similar lower realized h^2 estimate for EP40 was observed in PD-3 line chicken (Rajkumar *et al.* 2020b). Contrary to the present findings, higher realized heritability estimates were reported by Reddy *et al.* (2013) for EP40 in broiler chickens and Rajkumar *et al.* (2016) for SL6 in PD-1 line wherein the selection criterion was either body weight or shank length at six weeks of age. The realized and estimated heritability estimates tend to differ due to accumulation of inbreeding, segregation of genes, changes in gene frequency and/or mutations (James 1990).

The effective population size (Ne), selection intensity (i) and rate of inbreeding (ΔF) are presented in Table 5. The Ne was 167 in every generation. The selection intensity ranged from 0.44 to 1.10 and rate of inbreeding was 0.003 in the last five generations. Response to selection in the population was the function of Ne and the size of Ne was large enough to avoid any inbreeding as evidenced by the

Table 5. Effective population size, selection intensity and rate of inbreeding in PD-1 line

Generation	Sires	Dams	Effective Population size (Ne)	Selection Intensity (i)	Rate of inbreeding (ΔF)
S-1	50	250	166.67	1.01	0.003
S-2	50	250	166.67	0.98	0.003
S-3	50	250	166.67	1.04	0.003
S-4	50	250	166.67	0.44	0.003
S-5	50	250	166.67	1.10	0.003

low rate of inbreeding in the population. The larger Ne aids in improving the genetic response by reducing the inbreeding depression as well as preventing the loss of desirable alleles due to genetic drift in the population (Dunnigton *et al.* 2013, Rajkumar *et al.* 2016). The selection intensity for the primary trait appears to be reasonably fair over the generations. This may be attributable to the reasonably large sample size used for selection in every generation.

The study concluded that, the selection response for EM52, the primary trait was significant with gradual increase of 237.4 g per each generation in PD-2 line. The improvement was observed in positive direction for all other production traits as correlated response. The improvement in PD-2, the female parent line will contribute to the increase in egg production and egg weight in terminal cross *Vanaraja,* a proven rural chicken variety for backyard poultry.

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