V. DISCUSSION

The investigation pertained to a synthetic strain of colored broiler dam line (PB2) being maintained at the All India Co-ordinated Project on Poultry Breeding for Meat (AICRP) located at the Bangalore campus of KVA&FSU, Bidar. The strain, PB2, has undergone selection for ten generations for juvenile body weight at six/five weeks of age during the period from 1994 to 2005.

5.1 NON GENETIC EFFECTS

5.1.1 Hatch effects

Least squares ANOVA revealed significant differences in the performance traits among the hatches within each generation (Tables 4.1 to 4.4). These hatch effects are non-genetic sources of variation and tend to mask the true genetic variation thereby precluding valid estimates.

Hatch effects in the present study did not show any conclusive trend as to determine the ideal period of hatching and the optimum number of hatches to raise the replacement progeny in order to minimize the environmental effects. Hatch effects may be induced by various factors such as the age and nutritional status of breeder parents, the time of emergence of chicks (hatching), the intervening periods between hatches, incubator conditions, discrepancies in egg size, sex ratio between hatches, brooder conditions, nutritional factors, grower stage management and most importantly, the climatic factors to which the breeder parents were exposed to. Skaller (1954) also advocated that the data should be corrected to nullify the hatch effects before estimating the genetic parameters. Least squares constants were fitted to data utilized in the present study as per Harvey (1966) to offset the hatch influence, wherever significant.

The fluctuations in the hatch means without revealing any trend pointed to a fluctuating environment provided to the pullets during their chick and grower stages. In the present study, the total period of hatch, when the chicks were produced was not unduly long. It was expected that any initial environmental vagaries due to hatching environment could have been overcome by the time the pullet body weight was recorded. It is reasonable to presume that reduction of climatic and managemental variations together with the uniform nutritional and vaccination programmes could have reduced the
variations in the performance of the hatches towards the completion of the investigation. Therefore, a more uniform condition with respect to floor space, feeder space and feed has to be provided for all the hatches, to minimize the hatch effects. Timely vaccination schedules, de-worming practices and the quality of feed are some of the environmental factors, which are to be kept uniform.


5.1.2 Sex effects for body weight at five weeks of age (BW5)

It is a universal phenomenon and well established too, that males of mammalian and also most avian species weigh heavier than the females for body weights at different ages. The results presented in Tables 4.5 and 4.10 further lend credence to this fact of sexual dimorphism. This differential performance between males and females might arise as a consequence of differential rate of cell multiplication (somatotrophy) brought about by the androgenic hormonal influence. It has also been viewed that faster cell multiplication rate in the males is due to the triggering effect of growth hormones on the receptor cells which may be lesser in females, thus possibly rendering differential growth rates between the sexes (Crawford, 1990). Sexual dimorphism in favor of the males for body weight as visualized in the present investigation (Table 4.10) is in conformity with the results of several such findings from literature (Prathap Kumar, 1978; Lokanath, 1980; Shivaprasad, 1993; Jayakumar, 1994; Amruthesha, 2000 and Khosravinia, 2005).

Further, it may be mentioned that higher body weight in males compared to females is due to the higher intensity of selection practiced for males since considerably less number of males are selected than females. From the consolidated information gathered from annul reports of AICRP (Anon., 1999, 2002, 2003d and 2004d), the intensity of selection practiced (in terms of selection differential) was observed to be higher in the males than females, which is expected to result in higher body weight of males.
It was logical to assume the discrepancies in body weight between sexes as non-genetic. In order to obtain precise estimates of genetic parameters, the data were corrected with the appropriate Least squares constants for the significant effects due to sexes.


5.1.3 Significance of generations

Prevalence of highly significant effects due to generations (Tables 4.6 to 4.9) for all the traits under study may be attributed to the outcome of selection as well as fluctuations in environment and their interactions at the time of this investigation.

Significant differences due to generations are desirable in selection experiments as they preclude evaluating the outcome of selection. Siegel (1962), Kuruvilla (1979) and Khosravinia et al. (2005) also reported significant differences due to generations in the course of selection experiments for improvement of body weight in different strains of meat type chicken. The present study conforms to the above reports.

5.2 LEAST SQUARES MEAN AND VARIABILITY

5.2.1 Hatch wise means and variability

With respect to the primary trait (BW5), the hatches in each generation showed considerable variation but the first hatch appeared to perform best, irrespective of the generations. This could be because of the favorable environment in the form of fresh brooder houses, new feed ingredients and the extra care and interest towards the first hatch of every generation.

It may be relevant to point out (Tables 4.11 to 4.17) that the coefficient of variation was different from hatch to hatch for the same trait and also its magnitude was different for different traits. This could be the consequence of the different individual response of the birds to the given environmental conditions, which in turn might have affected their performance from time to time. Besides this, different magnitudes of variability in the different traits could also be attributed to the different behavioral
responses of different traits to the same environment. However, the coefficient of variation as estimated in the present study is within reasonable limits of normal distribution.

The coefficient of variation furnished in Tables 4.11 to 4.13 for body weights which showed a decline as age advanced were reflective of the gradual acclimatization of the chicks to the stresses of the entirely new external environment of the poultry farm. The environmental stress in terms of temperature and humidity during brooding also could have been different as to cause physiological stress on the newly hatched chicks. Further, selection for body weight at five weeks and thereafter at 12 weeks of age against physical defects could have resulted in lower coefficient of variation for the body weights beyond five weeks of age.

The lowest mean egg production was observed during the first independent (25-28 weeks) / cumulative (EP28) segment of egg production up to 40 weeks of age and this was the influence of the early stage of the initiation of egg production cycle. During this period, the pullets had to overcome the stresses due to feed restriction during the growing period. Moreover, the factors like the virtual absence of the much required artificial light just after coming to lay, the change from grower to breeder mash and the change in nutrient contents (energy / protein ratio) also accounted for a lower egg production at this stage. The later stages of high egg production in the segmented parts were the periods of gradual acclimatization and approach to peak stage of production.

The per cent coefficients of variation in the populations that were highest during the first cumulative segment (EP28) and least during the third segment (EP36) (Tables 4.16 and 4.17) suggested that pullets traversed through rigors at the initiation of egg production. This could be a sequel to some of the physiological changes experienced by the pullets due to hormonal function (FSH, LH and prolactin), which may show a lot of vagaries between individuals. Several workers (Gilbert, 1967; Amin and Gilbert, 1970) have established the latter fact in earlier studies. When once the pullets in the initial period of egg production got gradually acclimatized to the prevailing environmental circumstances and the physiological status, variability would be expected to decline gradually at the later segmented parts of egg production period. Such fluctuations may
also happen at the fag end of laying period before molting as per the views forwarded by the same authors.

Sudha (1990) has pointed out the asymmetrical distribution of egg production up to 40 weeks of age showing a large variability in layer type chicken. The coefficient of variation of 20.4 per cent observed in the present investigation was reasonably low and a large variability was observed only during the first segments up to 28 weeks of age, thus pointing out the uniformity in management at least after 32 weeks of age (P2).

5.2.2 Generation wise means and variability

Phenotypic means are useful guides to evaluate the response over generations in long-term generation experiments. The mean of the strain over generations, along with the result of DMR test amply exposed the differences among them (Tables 4.18 to 4.20).

5.2.2.1 Body weights

1. Body weight at five weeks of age (BW5)

Body weight at five weeks of age (Table 4.18), being the primary trait of selection, showed significant improvement over the generations, indicating that the strain has positively responded to mass selection for juvenile body weight and the situation is desirable. The coefficient of variation for the combined sexes, showed a declining trend, further substantiating the efficacy of selection and the necessity of a modification in the selection programme for bringing about further improvement in the trait.

As per the sex sub-classes (Table 4.19), the juvenile body weight in both males and females improved significantly (P≤0.05) as generations advanced. Males in all generations were significantly heavier than females suggesting the existence of sexual dimorphism. The coefficient of variation in males showed a higher declining trend indicating the efficacy of the higher selection intensities employed for males. Females had much higher variability than males probably owing to their lower selection intensities.

The mean body weight at five weeks of age recorded in the present study was higher in magnitude, as compared to those recorded in the same strain maintained at the Ludhiana center of AICRP (Anon., 2003a and Anon., 2004a). However, the estimates are lower than the colored synthetic dam line maintained at the CARI center of AICRP (Anon., 2003c and Anon., 2004c). Prashanth Kumar (2005) has also observed a similar
trend in the earlier studies in the same strain at AICRP, Bangalore. These discrepancies might be due to the differences in the selection intensities applied to the populations over generations and more so the different environmental conditions prevailing in different locations.

2. Body weight at 20 weeks of age (BW20)

Pullet body weight at 20 weeks of age (Table 4.18) also changed over the generations. Pullets in S9 generation were heavier (P≤0.05) compared to those in the earlier generation, indicating an increase in the mean value of the trait over generations, occurring as a sequel to primary selection for juvenile body weight at five weeks of age. A non-uniform and ungrouped restriction in feeding was adopted between the hatches in S9 generation owing to their wide range of body weight at five weeks of age. This resulted in a less severe restriction in S9 compared to S8, wherein hatches were uniformly restricted. Pullets in S10 generation had a body weight intermediate between the other two generations. The considerable reduction in S10 could be attributed to the more uniform and intense restricted feeding program followed based on body weight groups from six to 20 weeks of age, in the absence of which the pullets would have been heavier than the earlier generations. The coefficient of variation decreased in S9 but it increased to a maximum value of 28.4 per cent in S10 generation, under the artificial environment of restricted feeding.

The mean body weight at 20 weeks of age recorded in the present study was lower in magnitude, as compared to those recorded in the same strain tested at Ludhiana center of AICRP (Anon., 2003a and Anon., 2004a). The estimates were also lower than those reported in dam line at Bhubaneshwar center, indicating that restricted feeding has been effective in attaining the desired body weight at this stage in the population under study. The estimates were however higher than that of a synthetic dam line as reported by Kumar et al. (1994) and Madapurada (2001) in the same strain at the same location. The discrepancies for the same strain at the same location are attributable to the differences in the degree of restriction in feeding at various years, the population size under study, and the variances concerned.
3. **Body weight at sexual maturity (BWSM)**

   Body weight at sexual maturity also showed a similar trend as that of the pullet body weight. The coefficient of variation for the trait also fluctuated in a similar manner. The reasons identified for the pullet body weight would hold good for this trait also.

   The mean body weight at sexual maturity recorded in the present study was lower in magnitude, as compared to those recorded in the same strain tested at Ludhiana center of AICRP (Anon., 2003a and 2004a). Kumar *et al.* (1994) has reported higher estimates in a synthetic dam line. Madapurada (2001) has also reported higher estimates in the same strain at the same location.

4. **Body weight at 40 weeks of age (BW40)**

   The generation means and coefficient of variation of the mature body weight at 40 weeks of age also depicted a similar trend as that of the earlier body weights at pullet stage.

   The mean body weight at 40 weeks of age recorded in the present study was lower in magnitude, as compared to those recorded in the same strain tested at Ludhiana center of AICRP (Anon., 2003a and 2004a). Much higher estimates are reported for the dam line of a different strain maintained at Bhubaneshwar center (Anon., 2003b and Anon., 2004b).

5. **2.2 Age at sexual maturity**

   The pullets of S9 generation matured earlier by 12.05 days ($P\leq0.05$) than those of S8 generation. The pullets of S10 generation matured late ($P\leq0.05$) compared to the previous generations, as a result of the substantial reduction in pullet body weight at 20 weeks of age under the restricted feeding program. There was a steady decline in the coefficient of variation for the trait over the generations.

   The strain under present study appeared to have matured earlier than other synthetic dam lines (Kumar *et al.*, 1994) and the colored dam line at Bhubaneshwar center (Anon., 2003b and Anon., 2004b). However, the same strain at Ludhiana center had still lower estimates for age at sexual maturity (Anon., 2003a and 2004a). This might have been due to the different agro-climatic conditions of the locations, the differences in population size and the degree of feed restriction adopted in the populations over the generations.
5.2.2.3 Egg weights at 32 and 40 weeks of age

Egg weight at 32 weeks of age in the S9 generation was significantly (P≤0.05) lower when compared to S8 and S10 generations wherein the pullets matured early and a negative selection differential was employed for the trait indirectly in the S8 generation. However, under the restricted feeding program and the consequent delay in sexual maturity, the trait improved in S10 generation. Even though there was fluctuation in egg weight at 32 weeks, the same trait measured at 40 weeks of age decreased, the decline however being non-significant (P≤0.05). The coefficient of variation for the egg weights measured at both the ages showed an increasing trend over the generations, indicating scope for improvement in the trait through appropriate selection methods.

The other probable causes of the marginal decline in egg weight, (though not significant) could be the second stage mass selection for egg number up to 40 weeks of age (EP40) in the population and a consequent positive response in egg number, which has negative genetic correlation with egg weight, thus predisposing the pullets to lay smaller eggs. This decline in egg weight is not desirable and has serious setbacks with respect to production of settable eggs and thereby number of chicks obtained per dam. Hence, in order to overcome this problem, it is suggested to prefer and opt for selection for egg production superimposed with independent culling level selection for egg weight. But since the heritability of the trait in the strain (Table 4.26) is very low, improvement of egg weight over the generations would not be rapid through this method. Hence, adoption of a restricted selection index incorporating egg number and egg weight appears to be the most viable option.

The mean egg weight at 32 weeks of age recorded in the present study was lower in magnitude, to those recorded in the same strain tested at the Ludhiana center of AICRP (Anon., 2003a and 2004a). They were also lower than in other synthetic dam lines (Kumar et al., 1994) but comparable with the reports on dam line at Bhubaneshwar center (Anon., 2003b and Anon., 2004b). However, the mean egg weight at 40 weeks of age in the strain was higher than those recorded in the same strain at Ludhiana (Anon., 2003a and 2004a) and the dam line at Bhubaneshwar center (Anon., 2003b and Anon., 2004b).
5.2.2.4 Egg production up to 40 and 52 weeks of age

The egg production up to 40 and 52 weeks of age fluctuated over generations suggesting that the trait did not respond linearly over generations. Several factors other than genetic, namely changes in environmental attributes (temperature and relative humidity), quantity and quality of feed ingredients (restricted feeding) and other variable factors of environmental nature can be accounted for this type of inconsistent trend. The birds of S9 generation laid significantly more number of eggs (to the extent of 7.64 eggs at 40 weeks and 3.74 eggs at 52 weeks) than those of S8. This could have been due to the early sexual maturity in S9 generation. The birds of S10 generation produced least number of eggs at 40 and 52 weeks of age, as a result of the delayed sexual maturity under the influence of restricted feeding programme. However, it may be noticed (Table 4.18) that they have remained in production for a longer time (up to 72 weeks) and thereby contributed comparable number of eggs when compared to the earlier generations without any undesirable deterioration in egg weights, thus proving this sort of nutritional maneuvering to be effective in prolonging the production life of the flock.

The variability for egg production at 40 and 52 weeks of age showed a fluctuating trend accompanied with reasonable magnitudes indicating the scope for improvement in the trait through appropriate selection methods.

Part term egg number ranging from 70 to 78 eggs at 40 weeks of age and 90 to 121 eggs at 52 weeks of age in PB2 strain under AICRP at different locations has been reported (Anon., 2003a and Anon., 2004a). Egg production in the strain under evaluation in this study compares well with these reports. The egg production at 40 weeks of age was however higher than those reported for the dam line maintained at the Bhubaneshwar center (Anon., 2003b and Anon., 2004b).

5.2.2.5 Segments of egg production up to 40 weeks of age

A perusal of Table 4.20 on independent and cumulative segments of egg production up to 40 weeks of age indicated a marked decline in egg number up to 28 weeks of age (to the extent of 4.26 eggs) in S10 compared to S9 generation. This could be due to the lesser number of birds in production during the period, P1, owing to the delayed maturity resulting from the more intensive feed restriction in S10. The egg production during the remaining independent segments, P2, P3 and P4 did not differ
significantly between the generations, even though ASM was much delayed in S10 generation.

When cumulative segments were considered, the decline of egg number in S10 compared to S9 was more pronounced, to an extent of 4.26, 7.18 and 6.85 eggs, during the first (EP28), second (EP32) and third (EP36) segments. The effect of the delayed maturity on the first cumulative segment (EP28) seemed to get carried over to the later segments, because such a trend was not visible when independent segments above 28 weeks were studied.

The coefficient of variation for the independent and cumulative part records showed a declining trend as segments advanced. The variability for almost all the segments was higher in S10 when generations were compared.

5.3 HERITABILITY

The heritability estimates on sire component of variance for the various traits under study in PB2 strain have been presented in Tables 4.26 to 4.29. Heritability estimates of the same trait varied in magnitude over the generations and this is attributable partly to sampling and partly to real differences between populations and individuals due to selection.

The estimates for all the traits were reliable since the number of individuals measured in each generation was fairly large. Robertson (1959) had pointed out the importance of family structure, if reasonable heritability estimates from sire or dam are to be obtained. Falconer (1967) suggested the optimum size of family and also the kind of family selection to be adopted depending on the magnitude of heritability of the trait. In the present study, the size of family (K coefficients) appeared to be reasonably large to obtain reliable estimates (Table 4.21). The pooled estimates over generations were also computed because they would be preferable over single generation estimates as they consider the time trends in long-term selection experiments (Kinney and Schoffner, 1965).

5.3.1 Body weights
1. Body weight at five weeks of age (BW5)

The heritability estimates observed for body weight at five weeks of age (Table 4.26), the primary trait, were quite low, despite the fact that body weight is a highly heritable character. The low estimates with a declining trend over the generations might be the reflection of the gradual exhaustion of additive genetic variance as a result of effective long-term selection for the trait in this line. This also suggests that, before possibly approaching selection limits, suitable changes need to be made in the selection programme employed in the population.

It is obvious that different criterion of selection and intensities used for the selection of male and female breeders might have resulted in different heritability estimates in the two sexes (Table 4.27). The declining trend of heritability was apparent for the trait in both the sexes. The heritability estimates of males were slightly higher than that of the females in all generations. Since males were subjected to higher intensity of selection than females in all the generations, lower estimates of heritability were generally expected for males compared to females. Therefore, the higher estimates in males could be an indication that sex-linked genes are important in the inheritance of juvenile body weight at five weeks of age. Sex-linked effects may exist because, the sex-linked genes determining body weight might have got located on the sex chromosome, at the time of synthesis of PB2 strain from different commercial stocks.

The importance of additive sex-linked genes in the inheritance of juvenile body weight has been reported by many investigators (Aggarwal, 1975; Prathapkumar, 1978; Kuruvilla, 1979 and Puttaswamy, 1979). The findings in the present study are in conformity with the above reports.

As the selected lines have already undergone considerable length of selection, it seems reasonable to introduce some new genetic variation or to adopt the Recurrent Reciprocal Selection breeding programme for possibly improving further the purebred performance, utilizing the crossbred progeny performance.

The heritability estimates for body weight at five weeks of age (combined sexes) obtained in the present study are comparable with those reported by Singh et al. (2003b). They are however lower than the reports of Sati et al. (1999), Mustafa Khan (2003) and Dev Roy et al. (2005) in various synthetic flocks. Kishore et al. (2002) has reported a
higher estimate in the same strain (PB2) at a different location. The heritability estimates for females are comparable with the reports of Singh et al. (2003b) but the estimates in males are lower than those reported by Singh et al. (2003a) and Singh et al. (2003b) in earlier studies on the same sex groups.

Heritability, being a ratio is likely to change with change in the genetic material and / or in the environment. Environment differs from place to place and the hereditary material is not the same in all flocks. For this reason, the heritability is likely to vary, not only for the same trait at different places but also in different generations within a strain according to the selection practices followed (Lerner, 1950). The wide range of heritability estimates reported in literature could be attributed to several factors, majority of which are inaccuracies and differences in measurements, inherent errors in the data and the differences attributed to the statistical methodology adopted.

2. Body weight at 20 weeks of age (BW20)

The heritability estimates obtained for BW20 in this investigation were moderate in magnitude in all the generations, thus indicating the importance of additive genetic variance in the inheritance of this trait. The moderate magnitudes of this otherwise highly heritable trait could have been the consequence of the effective selection for earlier body weight at five weeks of age. The first stage selection for high juvenile body weight at five weeks of age and the later screening for physical defects at 12 weeks of age might also have resulted in moderate estimates for this body weight.

The estimates in the present study are comparable with those reported by Singh et al. (1988) in a synthetic flock, Shivekumar et al. (2003) in a synthetic dam line and Anon., (2004e) in control broilers. Estimates of lower as well as higher magnitude than the values observed in the present study have been reported in the literature. The probable reason for these discrepancies could be the period and location of breeds, methodology followed for obtaining the estimates, differential genetic strains etc. Lower (Madapurada, 2001) and higher estimates (Prashanth Kumar, 2005) have been reported for the same strain at the same location and these discrepancies could be attributed to differences in size and variance of the populations under study.

3. Body weight at sexual maturity (BWSM)
The heritability estimates obtained for body weight at first egg were generally moderate in magnitude in all the generations.

The estimates in the present study are comparable with almost all of the reports in various sire and dam lines of meat type chicken (Singh et al., 1988; Singh et al., 1995; Singh et al., 1999 and Kumar et al., 2001). The estimates also tally with the reports of Madapurada (2001) in the same strain at the same location.

**4. Body weight at 40 weeks of age (BW40)**

Mature body weight at 40 weeks of age was found to be moderately heritable in the strain. The estimated values were in close agreement with the reports of Sharma et al. (1983), Panda et al. (1987), Singh et al. (1988), Reddy et al. (1997) in various synthetic flocks and Shivekumar et al. (2003) in a synthetic dam line.

However, the estimates were higher than those reported in the same strain at the same location by Madapurada (2001). This could be attributed to the differences between the generations under study, with respect to the population size and the variances, since the mean value of these traits also become different.

In general, the heritability estimates of all the body weights beyond five weeks of age remained at a moderate level, in consequence to the reduced additive genetic variance due to direct selection for body weight at five weeks of age. This further established the pleiotropic nature of genes controlling body weights at different ages.

**5.3.2 Egg production and Allied traits**

1. **Age at sexual maturity (ASM)**

The heritability estimates of age at sexual maturity, which ranged from 0.231 to 0.382 over the generations (Table 4.26) suggested moderate involvement of additive genes in the inheritance of the trait. The medium estimates indicated that scope exist for any kind of desirable change in ASM through family or combined selection.

The moderate estimates obtained in the present study are comparable with those reported by Singh et al. (1995) in synthetic sire lines, Anon., (2003e) in control lines and Shivekumar et al. (2003) in a synthetic dam line. However, Prashanth Kumar (2005) has reported a lower estimate in the same strain in an earlier study at the same location, attributable to the reasons mentioned earlier.

2. **Egg weights**
Contrary to the findings of most of the literature cited earlier, the egg weight in the strain under study is found to be lowly heritable. The low heritability suggests the influence of non-genetic factors. Although criterion of selection undertaken for the populations in this study has been high juvenile body weight at five weeks of age, some pressure from natural selection for egg weight may operate at the time of hatching. Same set of pleiotropic genes is found to influence body weight and egg weight at different ages as indicated by the high positive genetic correlations of egg weights at 32 and 40 weeks with the body weight at five weeks of age (Tables 4.32 and 4.33). This in part might have accounted for a reduction in their available genetic variance as a correlated response, on direct selection for early body weight. Sharma et al. (1984) has reported a similar situation in a synthetic flock of meat type chicken.

The estimates in the present study are in accordance with Sharma et al. (1984), Mishra et al. (1986) in synthetic flocks, Kumar et al. (2001) in a synthetic dam line and the reports of Madapurada (2001) and Prashanth Kumar (2005) in the same strain at the same location.

3. Egg production up to 40 weeks of age (EP40)

The heritability estimates of EP40 were low ranging from 0.114 (S9) to 0.202 (S8) over the generations, which is an expected situation. The estimates had a fluctuating trend indicating the inconsistency of the already low additive genetic variance and / or the environmental conditions. The pooled estimate was also low but precise (0.150 ±0.049).

It may be recalled (Table 4.23) that the sire families accounted for 56 (S9) to 63 (S8) per cent of the total phenotypic variability of egg production up to 40 weeks of age (EP40). The R² values for EP40 suggest that extraneous factors to the extent of 36.4, 43.8 and 41 per cent influenced the variability in the trait, respectively in S8, S9 and S10 generations. These factors would be genetic, non-genetic, maternal effect and other intangible error sources of variation.

The low heritability estimates suggest that there has been some degree of depletion of additive genetic variance for EP40, owing to the positive response to selection employed for this trait over the past several generations. Majority of reports in literature on part period egg production, indicate the trait to be lowly heritable. Therefore,
the reasonable estimates in the present study indicate that selection method adopted was quite effective to exploit the additive genetic variance.

It is well documented that heritability of a particular character varies from population to population / over generations due to size of the population, available genetic variability, breeding structure and the time of study. The estimates were reasonably in the range expected for egg production, indicating scope for further improvement.

The estimates in the present study are in agreement with the reports of Singh et al. (1999) and Shivekumar et al. (2003) in synthetic dam lines and Anon., (2004b) in dwarf broilers. However, they were higher than those reported by Madapurada (2001) in the same strain at the same location, the lower estimates in the earlier study attributable to the restriction of the study to three hatches only.

4. Egg production up to 52 weeks of age (EP52)

The heritability estimates of egg production up to 52 weeks of age were low to moderate ranging from 0.169 (S9) to 0.342 (S8) over the generations. The estimates had a fluctuating trend indicating the inconsistency of additive genetic variance. The pooled estimate was also low but precise (0.194).

The heritability estimates of part period egg production up to 52 weeks of age was higher than the part period egg production up to 40 weeks of age. This might be due to the presence of considerable amount of unexploited additive genetic variance, in the absence of any direct selection for the trait at 52 weeks of age. Instead, the strain was undergoing sire family selection for egg production at 40 weeks of age, for the past several generations. Another reason could be the reduction in environmental variance on account of the longer period of production, where the random effect of environment get cancelled out. The results indicate that available additive genetic variance at 52 weeks of age for egg production can be exploited to bring about improvement in the trait by suitable selection method.

Similar but slightly higher heritability estimates have been reported for different extended part periods in layer type chicken by Sandhu and Dev (1972) who reported increase in heritability estimates with increase in egg production periods from two months to eight months, and Ayyagari (1979) and Venugopal (1996) who reported
similar magnitudes of heritability, suggesting higher estimates with increased part records. Similar studies on such extended part period egg production in broiler breeder populations were not available to make effective comparisons.

5.3.3 Segments of egg production up to 40 weeks of age

1. Independent segments of egg production (P1, P2, P3, P4)

It can be expected that in a broiler dam line of synthetic origin (PB2) maintained as a closed flock and subjected to long-term selection for egg production (EP40) in addition to juvenile body weight, variances of non-additive genetic nature are important. As a result, the magnitude of heritability estimates of egg production in different independently segmented periods were quite low (Table 4.28), ranging from 0.123 (P4) to 0.280 (P1) in S9 generation and 0.005 (P3) to 0.273 (P1) in S10 generation. The pooled estimates also varied in similar fashion ranging from 0.039 (P4) to 0.260 (P1).

The estimates of heritability during most of the independent segments were associated with low standard errors and therefore precise. So it can be opined that the sire family selection being practiced in the dam line (PB2) for improvement of egg production has proved effective. However, increasing the family size as well as the number of families can bring about further improvement in the egg production.

Significance of variance in sire families was observed among the earlier segmented periods, P1, P2, P3 in S9 generation and P1, P2 in S10 generation. This suggested the prevalence of additive genetic variability among the sire families. But, towards the later segments in both the generations viz., P4 in S9 and P3, P4 in S10 generation, sire families lacked additive genetic variance as indicated by their non-significance. The co-variance in sire families also turned out to be non-significant, as also the variance in sire families. This was particularly evident in S9 (P4 X EP40) as well as S10 generation (P3 X EP40, P4 X EP40). This indicated that egg production during the late periods, P3 and P4, was depleted of variances and co-variances as a consequence of long-term sire family selection, undergone by the strain. Hence, egg production during the later period from 33 to 40 weeks of age seemed to be under the strong control of non-additive genetic variance such as dominance and epistatic variances besides the non-genetic factor of maternal influences. This would reinstate the need of maintaining individual egg production records on dam-family basis (full-sibs). Perhaps, the finding is
reasonable because the broiler parental line PB2, presently being studied has nicked well with PB1 parental line males for commercial chick production on crossing with PB2 as the maternal parent. Adoption of proper managerial practices like nutritional maneuverings and artificial light prior to and during this period would also be conducive to enable the birds to approach and maintain peak production.

The estimates obtained in the present study are comparable with the reports of Reddy (1996) on independent segments of 21-day duration in a colored broiler male line. No more references were available on this kind of study in broiler breeders to make effective comparisons on a wider base.


Significant variance in sire families observed for all the cumulative part records (Table 4.25) suggested the prevalence of a certain amount of additive genetic variability among the sire families throughout the segments.

The heritability estimates of various cumulative part records up to 40 weeks of age (Table 4.29) were found to be low to moderate ranging from 0.184 to 0.268 for EP28, 0.151 to 0.207 for EP32 and 0.154 to 0.164 for EP36 in two generations of PB2. The estimates showed decreasing trend in magnitude as the duration of record of egg production increased. The reason being, egg production measured as number of eggs produced to different ages, is influenced by age at sexual maturity. So it is possible that as part period becomes longer, the cumulative egg number contains a decreasing amount of variance caused by age at sexual maturity as well as the random effect of environment. This would suggest that as long as age at sexual maturity has a significant effect on early part records, it would inflate the heritability estimates.

It can also be noticed that (Table 4.26) the estimate for later stage of egg production (EP40) was lower than the estimates for cumulative part records at earlier stages (EP28, EP32, EP36), indicating less influence of ASM, in comparison to earlier part records. This also supports the view that estimates of early part records get more inflated under the influence of age at sexual maturity.

The estimates in the present study are lower than those reported by Sakunthala Devi (2002) in a WLH population for accumulative segments to 30 and 38 weeks of age.
Similar reports on broiler parental populations were not available to make effective comparisons.

5.4 CORRELATIONS

5.4.1 Among body weights at different ages

1. Juvenile body weight (BW5) with body weight at 20 weeks (BW20)

The strong positive moderate genetic correlations between body weights at five and 20 weeks of age indicate that birds heavier at five weeks would have higher body weight at 20 weeks, which is generally the time closer to the onset of sexual maturity. Since an optimum body weight is required at the onset of sexual maturity for an optimum egg size and good egg number, the selection of prospective layers can be wisely undertaken at five weeks of age using this relationship. The phenotypic correlations were lower but positive and generally significant indicating the favorable influence of the environment over the association.

Most of the available reports in literature have indicated similar positive associations between the traits (Panda et al., 1987; Singh et al., 1988; Reddy et al., 1997 and Prashanth Kumar, 2005).

2. Juvenile body weight (BW5) with Body weight at sexual maturity (BWSM)

The strong positive and significant moderate to high genetic correlations between body weights at five weeks of age and at sexual maturity suggest that juvenile body weights are earlier indicators of subsequent body weights and these body weights are therefore influenced by the same set of genes. So, body weight at sexual maturity could be improved or optimized by the selection for earlier body weights, as a correlated response. It is also cautioned that selection for higher body weight at five weeks of age would make the pullets too heavy at sexual maturity and result in a delayed maturity, if the weight gain after five weeks of age were not
kept under control through effective managemental practices. The phenotypic correlations were low, positive and significant indicating the favorable influence of the environment over the association.

The estimates observed in the present study are in conformity with the reports of Singh et al. (1988) in synthetic flock and Prashanth Kumar (2005) in the same strain (PB2).

3. Juvenile body weight (BW5) with body weight at 40 weeks (BW40)

The strong moderate to high positive genetic correlations between body weights at juvenile and mature stages indicate that body weights at different stages show a linear trend and that they are governed by the same set of genes. The phenotypic correlations were low and positive but significant only in S10, indicating the positive influence of the environment on the association in the concerned generation.

The positive associations obtained between the traits fall in accordance with the findings of Sharma et al. (1983) but contrary to those of Panda et al. (1987) and Singh et al. (1988) who have reported negative relationships.

4. Body weight at 20 weeks (BW20) with Body weight at sexual maturity (BWSM)

The positive moderate to high genetic correlations between body weights at 20 weeks of age and at first egg suggest that some optimum body weight at 20 weeks is necessary for attaining sexual maturity. The faster growth up to 20 weeks of age allows faster attainment of this optimum body weight and early sexual maturity is attained through this positive association.

Several authors have reported similar estimates in various synthetic flocks (Singh et al., 1999 and Kumar et al., 2001) and in the same strain, PB2 (Madapurada, 2001 and Prashanth Kumar, 2005).

5. Body weight at 20 weeks (BW20) with Body weight at 40 weeks (BW40)

Body weight recorded at different times is expected to show a positive trend generally. This was firmly represented in the form of genetic and
phenotypic correlations presented in Table 4.30. The strain showed the likelihood of a strong association between the traits in that pullets heavier at 20 weeks of age continued to be heavier at 40 weeks also. The phenotypic correlations were low, positive and significant indicating the positive influence of the environment over the association.

The positive estimates obtained in the present study are in agreement with most of the reports (Singh et al., 1988; Poonia and Jithendrakumar, 1995; Reddy et al., 1997; Singh et al., 1999) but Madapurada (2001) has reported negative associations between the traits in the same strain, probably because of the smaller population size considered in the study.

6. Body weight at sexual maturity (BWSM) with Body weight at 40 weeks (BW40)

The body weights at sexual maturity and at mature stage (40 weeks of age) were found to have moderate to high positive genetic correlations. Similar estimates were observed between the traits by Singh et al. (1988) and Singh et al. (1999) in various synthetic flocks and sire line respectively, and also by Madapurada (2001) in the same strain (PB2). The phenotypic correlations were low, positive and generally significant indicating the positive influence of the environment over the association.

5.4.2 Body weights and Age at sexual maturity (ASM)

1. Body weight at five weeks of age (BW5) and Age at sexual maturity

The negative low to moderate genetic correlation between the traits indicate that higher the body weight at five weeks of age, the birds would mature earlier. This situation is possibly attributed to the fact that the birds were initially selected for higher early body weight and only the selected individuals were included in the estimation of correlations with the subsequent traits. The estimates were not high but low to moderate under the effect of the selection at five weeks of age. The phenotypic correlations were low and positive but not reliable due to high standard errors, and these estimates being limited in validity, gave no idea on the influence of the environment over the association.

Similar findings have been reported in synthetic flocks (Singh et al., 1988) and in the same strain (Prashanth Kumar, 2005) in earlier studies.
2. **Body weight at 20 weeks of age (BW20) and Age at sexual maturity**

The genetic and phenotypic correlations between ASM and BW20 were negative over the generations ranging from medium to high. These estimates indicated that those birds, which were heavier at 20 weeks, matured earlier. It may be noted that the body weight at 20 weeks of age was closer to the optimum (targeted) body weight of 2200 g in S8 and S10 generations and hence the correlations in the concerned generations turned out to be stronger, compared to that in S9 generation. Hence, the current practice of restricted feeding is effective and beneficial to arrive at an optimum pullet body weight and age at maturity. Through this type of nutritional maneuvering, the body weight at 20 weeks is kept optimum for the entire flock, making it look uniform and thus delay their maturity. This would increase the egg production and duration of their productive life and maximize the number of chicks obtained per dam, in the long run.

The negative associations between body weight at 20 weeks of age and age at sexual maturity in the present study are in agreement with Johari *et al.* (1987), Singh *et al.* (1988) and Kumar *et al.* (2001) in various synthetic flocks and Prashanth Kumar (2005) in PB2 strain.

3. **Body weight at sexual maturity (BWSM) and Age at sexual maturity**

The phenotypic and genetic correlations between the body weight at sexual maturity and age at first egg were low to medium. The negative genetic correlations indicated that heavier birds matured earlier. This pointed out the need to maintain an optimum body weight at sexual maturity, which is partly met with the restricted feeding during 6-20 weeks of age.

The negative low to moderate genetic correlations obtained in the present study are in agreement with the positive associations reported by Singh *et al.* (1999) in synthetic flocks and Prashanth Kumar (2005) in the same strain, PB2.

4. **Body weight at 40 weeks of age (BW40) and Age at sexual maturity**

The strong moderate negative genetic associations between age at sexual maturity and mature body weight at 40 weeks indicated that early maturing birds are genetically predisposed for a heavier body weight at 40 weeks of age. The phenotypic correlations were low with fluctuating trends and significance over the generations, except for the
positive estimate in S10, indicating the contrasting influence of the environment over the association in the concerned generation, when compared to the genetic trend.

Body weight at 40 weeks at age, should not be of much concern in a broiler enterprise, other than their salvage point of view at the time of disposal, since unlike in a layer enterprise, it is not customary to maintain the broiler breeders up to 72 weeks of age. On the other hand, pullets very heavy at 40 weeks of age are undesirable from productive point of view, if they are targeted to produce more number of settable eggs after 40 weeks of age in order to raise the replacement progeny. Therefore, it is most necessary to curtail excessive body weight at mature stage, which can be attained through some kind of nutritional maneuvering like optimal feeding based on the level of production, thereby preventing over-feeding after sexual maturity.

The negative genetic correlations obtained in the present study are in accordance with the reports of Singh et al. (1999) in synthetic flocks.

5.4.3 Body weights and Egg weights

5. Body weight at five weeks (BW5) and Egg weight at 32 and 40 weeks

The positive moderate to high genetic relationship between juvenile body weight and egg weights at 32 and 40 weeks of age in the present study indicated that birds heavier at five weeks are likely to produce larger eggs at 32 and 40 weeks of age. The phenotypic correlations were low, positive and generally significant indicating a similar influence of the environment as that of genetic association.

Increase in egg weight following selection for juvenile body weights due to their positive association have been reported by many (Seigel, 1962; Ideta and Seigel, 1966; Reddy and Seigel, 1977; Singh et al., 1988) in various meat type chicken and Prashanth Kumar (2005) in the same strain at the same location.

6. Body weight at 20 weeks (BW20) and Egg weight at 32 and 40 weeks

The trend in the positive genetic association between body weight at 20 weeks and egg weights suggest that an optimum body weight at 20 weeks of age would favor an optimum egg weight at 32 and 40 weeks of age. The phenotypic correlations were low with fluctuating signs and significance, except for the significant estimate in S8,
indicating the environment to be in opposite direction as that of the genetic predisposition in the concerned generation.

The present results as well as the literature reports in synthetic flocks (Singh et al., 1985) and in the same strain, (Madapurada, 2001) confirmed the positive relationship of the two traits.

While the Table 4.31 emphasized the favorable association of BW20 with ASM, it is still more critical to study its association with egg weights. The present study did not suggest any evidence for the likelihood of a possible deterioration in egg weights (Table 4.32) despite the expectation of the pullets to reach sexual maturity at an optimum age and lay with good persistency, when the weight at 20 weeks is kept optimum. The critical role of the early identification of pullets based on BW20 is depicted in these correlations, emphasizing the breeder’s role in identifying the optimum level of BW20 in the pullets for ensuring optimum age at sexual maturity and persistent egg production with desirable egg weight.

7. **Body weight at sexual maturity (BWSM) and Egg weight at 32 (EW32) and 40 weeks (EW40)**

The positive genetic relationship between body weight at sexual maturity and egg weights in the present study are in close agreement with Kumar et al. (2001) in synthetic flocks and Madapurada (2001) and Prashanth Kumar (2005) in the same strain (PB2). All the phenotypic correlations were low and imprecise due to high standard errors, making it difficult to understand the influence of environment over the association. The interpretations mentioned about the relationship of egg weights with BW20 would hold well with body weight at sexual maturity also, since the latter is only an extended expression of BW20.

8. **Body weight at 40 weeks (BW40) and Egg weight at 32 and 40 weeks**

The positive genetic relationships as furnished in Tables 4.32 and 4.33 indicate that birds giving optimum sized eggs at 32 weeks of age would remain with optimal body weight at 40 weeks of age. Similarly, the genetic relationships between egg weight at 40 weeks and mature body weight observed to be stronger than the corresponding phenotypic associations indicated the possibility of getting heavier eggs from heavy mature birds to which they were genetically predisposed. This was not surprising since
both are weight-oriented measurements of body and egg, and measured around the same age. Therefore, they are expected to be under the same genetic control, resulting in a positive relationship of reasonable degree. The gene action involved appeared to be chiefly pleiotropy. The phenotypic correlations being low, positive and significant indicated a similar influence of the environment on the association between the traits.

The positive relationships between body weight at 40 weeks of age and egg weights in the present study are in close agreement with Reddy et al. (1997) in synthetic flocks and Madapurada (2001) and Prashanth Kumar (2005) in the same strain (PB2).

5.4.4 Body weights at different ages and Egg production up to 40 (EP40) and 52 (EP52) weeks of age

1. Body weight at five weeks (BW5) and Egg production

The low to moderate positive genetic relationship between body weight at five weeks and egg production up to 40 and 52 weeks, suggest the trend of mass selection based on body weight at five weeks of age, to be in the desirable direction without adversely affecting the egg production. The egg production at 52 weeks was more strongly correlated at genetic level with the juvenile body weight at five weeks of age, compared to egg production at 40 weeks of age. The phenotypic correlations were low, but fluctuated in signs and were significant only in S9, indicating a similar influence of the environment as that of genetic association only in the concerned generation.

Sharma et al. (1983) has reported a contrasting negative genetic relationship between the traits in a synthetic flock. However, Singh et al. (1988) has observed a genetic association of similar magnitude and gene action as that of the present study. A positive association of lower magnitude was observed by Prashanth Kumar (2005), in the same strain when egg production at 32 weeks was considered, which could be attributed to the differences between the populations taken for study with respect to the population size and variances, since the mean value of these traits also become different.

2. Body weight at 20 weeks of age (BW20) and Egg production

From Tables 4.34 and 4.35, it can be observed that the phenotypic and genetic correlations between pullet body weight at 20 weeks and egg production to 40 and 52 weeks of age were positive and significant. Pleiotropic gene action appeared to be
responsible for this association. The magnitude of genetic correlations of BW20 with egg production up to 52 weeks of age were higher than those with egg production at 40 weeks of age, suggesting a stronger influence of BW20 on egg number at 52 weeks of age than at 40 weeks of age. The genetic correlations in S9 generation were lower than those in the other two generations, suggesting the pullet body weight to be closer to the optimum in S8 and S10 generations, when compared with S9 generation.

The low standard error of the genetic correlations, significance of the phenotypic correlations and the higher magnitude of genetic relationship over phenotypic relationship strongly supports the view that optimization of BW20 would genetically predispose the pullets towards high egg number even at later stages, a favorable situation to be exploited by the breeders.

The dam line pullets are mainly intended for egg production and on account of the positive relationship between these traits, it is suggested not to increase the BW20 any further, since pullets might be predisposed for abdominal fat deposition and obesity, resulting in decreased egg production. Hence, at this juncture, it is very important to stress on the critical role played by the pullet body weight at 20 weeks, at which stage, selection should be most effective. It can be suggested that BW20 being heritable to a moderate extent (Table 4.26) in this study, an independent culling level selection optimized for BW20 together with the ongoing restricted-feeding programme is expected to be beneficial in the future generations. In view of the above facts, a future study on identification of the optimum BW20 for efficient egg production based on body weight groups is warranted.

Part-period egg production has been reported to have similar positive associations with body weights at different ages by Fairfull and Gowe (1990).

Positive associations of similar magnitude and gene action of similar nature have been reported by Singh et al. (1988) and Singh et al. (1999) in various synthetic flocks and Madapurada (2001) and Prashanth Kumar (2005) in the same strain.

3. Body weight at sexual maturity (BWSM) and Egg production

Majority of genetic and phenotypic correlations of body weight at sexual maturity with egg production up to 40 and 52 weeks of age were positive, low to moderate and significant. The birds appeared to have the optimum body weight at sexual maturity as
evident from their positive relationship. This also indicated that birds that were heavy
(within the optimum range) at first egg were genetically predisposed to give more
number of eggs at 40 as well as 52 weeks of age.

The observable feature was that the genetic correlations were higher than the
phenotypic counterparts, clearly indicating more genetic control over the association of
these traits. The genetic correlations with EP52 were stronger than those with EP40 as
indicated by their higher magnitude. The trend of association suggested that pullets with
optimum BWSM from genetic causes could reasonably be pre-disposed genetically to
have good egg production even at later stages. The improvement expected in egg
production through an optimum BWSM would also be higher because of the strong
negative genetic correlations. Hence, the continued adoption of restricted feeding of the
grower birds is recommended to maintain the optimum body weight at first egg.

The positive genetic correlations observed in this study are similar to those
reported by Johari et al., (1987) and Kumar et al., (2001) in synthetic flocks and
Madapurada (2001) and Prashanth Kumar (2005) in the same strain.

4. Body weight at 40 weeks of age (BW40) and Egg production

The genetic correlations presented in Tables 4.34 and 4.35 between body weight
at 40 weeks of age and egg production at different ages (EP40 and EP52) were negative
and low to moderate. The phenotypic correlations obtained were weak and imprecise due
to high standard errors, in general. The scrutiny of the correlation estimates indicated
higher genetic correlations in comparison to their phenotypic counterparts.

The genetic correlations of mature body weight were stronger with EP52 than
with EP40 as indicated by their higher magnitude. These negative genetic correlations
suggested that adult body weight at 40 weeks of age was lower in pullets with higher egg
production potential. Alternately, the genetic tendency of the strain was a decline in
mature body weight at 40 and 52 weeks, when selection was performed for egg number
up to 40 or 52 weeks of age. This was not unexpected, because pullets in good production
utilize more of the energy and protein sources from feed towards production, after the
maintenance requirements for body weight are met with.

Besides this, it was detrimental to have birds heavy at 40 weeks of age, since it
would result in lowered egg production and thereby reducing the number of chicks per
dam. Beyond 60 weeks of age, the fertility of the cocks would decrease substantially and eggs produced may become over-sized, resulting in lowered hatchability. Therefore, if it was desired to measure egg production up to 60 / 72 weeks of age in the broiler breeders, it was advisable to control adult body weight, so as to ensure high rate of fertility and hatchability, such that economic gains would be better. As evident from their negative relationship, the birds did not seem to have the optimum mature body weight for efficient egg production. They seemed to be over-fed after their sexual maturity and hence, practices like optimal feeding based on the level of production and reduction in the energy and protein levels are desirable in dam line pullets to produce more number of eggs with better hatchability for a longer period.

The negative genetic correlations observed in this study are in concordance with those reported by Sharma et al. (1983), Johari et al. (1987), Singh et al. (1988), Singh et al. (1999) and Kumar et al. (2001) in synthetic flocks and Madapurada (2001) in the same strain.

5.4.5 Age at sexual maturity (ASM) and Egg weights (EW)

In congruence with the aim of improving egg production through reducing ASM, it is important to assess it’s impact on egg weight, since egg production and egg weight are negatively related and that an optimum egg weight is a prerequisite for high hatchability.

A perusal of relationship between the traits (Table 4.36) showed that the genetic and phenotypic correlations of ASM with EW32 and EW40 were generally positive and significant. The significant positive associations with EW32 suggested that, there is increased likelihood of getting heavier eggs at 32 weeks due to genetic causes, if the age at first egg is delayed. By delaying sexual maturity, an increased egg weight at 40 weeks was also observed, for which the genetic causes were most reliable. This positive association of ASM with EW40 also happens to be valid, considering the positive association between EW32 and EW40, as depicted in Table 4.39. The phenotypic estimates being lower than the corresponding genetic estimates, genetic control over the association seemed considerable.
These relationships reinstated the potentiality of the population for increasing or at least preventing any decline in egg weight at 32 and 40 weeks of age through achieving a late maturity. Therefore, egg weight at 32 and 40 weeks, being lowly heritable in the population (Table 4.26), could be improved to the desired level, by delaying the sexual maturity of pullets, which in turn can be efficiently achieved through the ongoing restricted-feeding programme.

Several associations similar in magnitude and trend to those reported in the present study, between age at sexual maturity and egg weight at 32 weeks, were also reported by Singh et al. (1999) and Kumar et al. (2001) in synthetic flocks and Prashanth Kumar (2005) in the same strain. The positive association of ASM with egg weight at 40 weeks is in conformity with reports in layer type birds (Johari et al., 1987).

5.4.6 Age at sexual maturity (ASM) and Egg production

The genetic correlation between cumulative egg production up to 40 weeks of age (EP40) and age at sexual maturity (Table 4.37) were negative with a magnitude of -0.648, -0.512 and –0.958 in the three generations of PB2. The corresponding estimates for EP52 (Table 4.38) were also negative with magnitudes of –0.604, -0.660 and –0.787. The results were in desirable direction, indicating that any attempt to improve EP40 or EP52 will result in concomitant decline in ASM as a correlated response. The strong negative relationship between the traits indicated a bright scope for reducing ASM in order to boost up egg production. Lending credence to this was the fact that ASM was heritable to a moderate extent in the strain such that suitable measures of selection could be effective in reducing it genetically.

The phenotypic correlation estimates also showed similar trend as that of genetic correlation, but were lower in magnitude. This entails one to achieve desirable progress in egg production due to phenotypic selection for early sexual maturity. This can also be achieved genetically towards which the strain had more predispositions. It is relevant to stress herewith that the magnitudes of the genetic correlations of age at sexual maturity with egg production at early periods like 28, 32, 36 weeks of age (Table 4.42) were generally higher than those with egg production up to 40 (EP40) and 52 weeks (EP52), thereby possibly suggesting the usefulness of selection on cumulative part records to improve egg production at later stages.
In view of this, however, it is cautioned that too early age at first egg is undesirable due to lay of small sized eggs. Hence, the genetic predisposition for high egg production being foreseen, it is wise to delay ASM only through nutritional and light management till such a time, when initial egg size is reasonably good, and also that birds with delayed maturity tend to have expectedly longer persistency of egg production during the late productive phase (beyond 52 weeks). This practice is in vogue with commercial poultry breeders.

Restricted feeding programmes are widely adopted to delay the onset of sexual maturity in broiler breeding stocks, especially the dam lines. Through this type of nutritional maneuvering, the body weight at 20 weeks is kept optimum for the entire flock, making it look uniform and thus delay their maturity in order to increase the long-term egg production. This would maximize the number of chicks obtained per dam in the long run.

Evidences to the consistent negative relationship between ASM and EP40, EP52 in meat type chicken are in plenty from literature (Sharma et al., 1983; Singh et al., 1988; Singh et al., 1999; Kumar et al., 2001; Prashanth Kumar, 2005) thus confirming the findings of the present investigation.

5.4.7 Egg production and Egg weights

Relationship between egg number and egg weight has a strong bearing on the economics of poultry breeding enterprises. A breeder desires high egg number of desirable weight from the point of view of hatchability performance. Therefore, a simultaneous improvement in both the traits is desired. From a broad review of the existing literature, it is well established that these traits manifest a strong negative association, which warrants the adoption of alternate breeding methodologies.

A perusal of Table 4.38 indicated strong moderate to high, consistently significant negative associations between cumulative egg production and egg weights, irrespective of age and generations. This implied that pullets which lay large-sized eggs showed poorer egg production, due to their genetic predisposition and physiological functioning. The phenotypic correlations were also negative but lower than the corresponding genetic correlations, thereby suggesting that the strain had a genetic disposition to have a decline in egg weight due to selection for egg number. This calls for the adoption of independent
culling level (ICL) selection for egg weight in order to arrest the decline in egg weight due to positive selection for egg production.

However, the heritability estimates of the egg weights in the present study are very low, leaving little scope for this type of selection to give a good response in promoting the trait. Since the breeder has been practicing selection for high BW5 and simultaneously aiming at reaching an optimum body weight at 20 weeks of age, the pullets have lost considerable variability with respect to these traits, over the generations. Therefore, taking into account the positive genetic correlations of BW5 and BW20 with egg weights at any stage, it may reasonably be expected that a considerable reduction in the additive genetic variance for egg weight has occurred as a correlated response, because of which the heritability estimates for egg weight were very low (Table 4.26). The heritability of egg weight may also decrease in pullets with high egg production, because of the absence of selection for poor layers giving good-sized eggs.

Improvement or prevention of decline in egg weight should not be a matter of serious concern in the present population because this would automatically be achieved to a certain extent through selection for early body weight at five weeks of age, due to their moderate positive genetic associations. Hence, owing to the multi-stage selection program currently in practice, any subsequent selection for egg number is not expected to hamper the progress in either egg number or egg weight, in spite of their antagonistic relationship. However, if a rapid improvement in both traits is targeted, a multi-trait restricted selection index incorporating egg weight and egg number would be the viable option. Alternately, selection for egg mass would prove beneficial to improve both egg number and egg weight simultaneously.

Negative genetic and phenotypic correlations of similar magnitude between egg weights and egg production to 40 weeks have also been reported by Sharma et al., (1983), Johari et al. (1987), Reddy et al. (1997) and Singh et al. (1999) in various synthetic flocks and Madapurada (2001) and Prashanth Kumar (2005) in the same strain.

5.4.8 Among egg weights at different ages

The moderate positive genetic correlations between egg weight at 32 and 40 weeks of age (Table 4.39) indicated the possibility of progress in egg weight from genetic selection at either of the ages. The phenotypic correlations were also positive but lower
than the genetic correlations indicating the superiority of genetic causes behind the association.

5.4.9 Segments of egg production up to 40 weeks of age

5.4.9.1 Among independent segments of egg production

1. Egg production during 25-28 weeks of age (P1) with other periods:

   It was apparent from Table 4.40 that in S9 generation, egg production in the first period P1, (25-28 weeks) was positively and highly correlated genetically with the cumulative egg production up to 40 and 52 weeks (EP40 and EP52). Most of the estimates with the remaining segments had high standard errors. The very high magnitude of genetic correlation of P1 with EP40 and EP52 suggested that gene loci involved in the genetic control of these traits were mostly common which could be due to pleiotropy. The phenotypic correlations with all periods except P4 were of low magnitude and significant.

   On the other hand, in S10 generation, the genetic correlations of P1 with other periods and EP40 were high and beyond unity. Genetic correlations beyond unity are not uncommon in literature arising due to (1) sampling errors (2) estimates of genetic standard deviations and their products were slightly smaller than the covariance between the traits involved, resulting in correlations beyond unity. The corresponding phenotypic correlations between P1 and other periods were of low magnitude but precise and significant.

2. Egg production during 29-32 weeks of age (P2) with other periods:

   The egg production in the second period, P2 (29-32 weeks) was also highly correlated genetically with EP40 and EP52 in both S9 and S10 generations, indicating the possibility of existence of pleiotropy. The phenotypic correlations of P2 with all other periods and EP40, EP52 were positive, medium to high in magnitude, precise and significant, irrespective of the generations. They were comparatively lower than the corresponding genetic correlations, suggesting that genetic scope existed for improvement in any of the traits through selection for egg production during P2 (29-32 weeks). So genetic progress could be expected from selection for egg production during the period, P2.
The overall trend from these results showed that egg production during initial periods (25-32 weeks of age) exercised a strong influence, genetically and phenotypically, on future egg production.

3. Egg production during 33-36 weeks of age (P3) with other periods:

In S9 generation, the genetic correlations of egg production during the third period, P3 with P4 (37-40 weeks), EP40 and EP52 were very high and significant. The estimate with P1 was of low magnitude and that with P2 exceeded unity. The corresponding phenotypic correlations ranged from low to medium in magnitude, and were precise and significant.

The genetic correlation of egg production during the third period, P3 with EP40 in S10 generation, was high but associated with high standard error. The estimates with other periods exceeded unity. The corresponding phenotypic correlations showed the same trend as that of S9 generation in magnitude and precision.

The trend of correlation estimates suggested that egg production during 33-36 weeks of age exercised a considerable influence on future egg production up to 40 weeks of age both genetically and phenotypically.

4. Egg production during 37-40 weeks of age (P4) with other periods:

The genetic correlation of egg production during the fourth period, P4 (37-40 weeks) with P3 (33-36 weeks) was very high and significant in S9 generation. But the genetic correlation with EP40 were non significant in both generations.

The phenotypic correlations with all other periods in both the generations were low to medium in magnitude and significant (P≤0.05), barring the non-significant estimate with P1 in the S9 generation.

5.4.9.2 Among cumulative segments of egg production

A perusal of the Table 4.41 indicate significant high and positive associations between cumulative egg production up to 40 and 52 weeks of age (EP40 and EP52) with early part record egg production up to 28, 32 and 36 weeks of age, as measured from the genetic and phenotypic sources, in both the generations of PB2.

The genetic correlations ranged from 0.672 to 1 (EP28 X EP40), 0.859 to 1 (EP32 X EP40) and 0.961 to 0.997 (EP36 X EP40) over the generations. The results indicate that, as the length of part record increased, the intensity of genetic correlation also
showed a linear increasing trend. This is not unexpected, since early cumulative part records themselves form the components of cumulative egg production up to 40 weeks of age. Hence, the very high genetic correlations observed in this study suggests that part records and total egg production up to 40 and 52 weeks of age could be reckoned as the expression of the same trait measured at different times. This could be because the same set of genes were controlling egg production at different times and that these could arise because the correlations are part or whole time relationships (pleiotropy).

The phenotypic correlations between EP40 and the cumulative part records were also positive and high ranging from 0.772 to 0.815 (EP28 X EP40), 0.691 to 0.907 (EP32 X EP40) and 0.471 to 0.966 (EP36 X EP40) over the generations. The higher phenotypic correlation of EP28 with EP40 in S9 generation, compared to the genetic correlation, is a matter of concern, indicating the poor genetic control over the association between the traits. This indicates EP28 to be probably a poor candidate for making the basis for an early selection towards improvement of EP40.

With EP52, the genetic correlations of different cumulative part records ranged from 0.645 to 0.972 (EP28 X EP52), 0.774 to 0.910 (EP32 X EP52), 0.922 to 0.957 (EP36 X EP52) and 0.831 to 0.872 (EP40 X EP52) over the generations, thus indicating a similar trend of more intense correlations with longer part records, as that with EP40. The phenotypic correlations between EP52 and the cumulative part records were also positive and moderate to high ranging from 0.492 to 0.466 (EP28 X EP52), 0.469 to 0.615 (EP32 X EP52), 0.442 to 0.702 (EP36 X EP52) and 0.495 to 0.520 (EP40 X EP52) over the generations.

The results, in overall, suggest that the selection on early cumulative part records would bring about concomitant improvement in cumulative egg production up to 40 as well as 52 weeks of age (EP40 and EP52) as a correlated response. So emphasis can be placed on selection for part records of egg production for improvement of full term egg production. The time gap between the traits can be saved in terms of maintenance cost, by disposing unwanted birds through proper selection for part records. Accordingly, the reduction in generation interval would result in faster genetic gain. However, this has to be carefully evaluated for the probable loss of residual egg production when practiced in the long run.
5.4.10 Age at sexual maturity and Segments of egg production to 40 weeks of age

5.4.10.1 Age at sexual maturity (ASM) and Independent segments

The significant negative genetic correlations between age at sexual maturity and the first period (P1) i.e. egg production during 25-28 weeks of age (Table 4.42), in both the generations implied that early maturing birds had more egg production during the initial period, which is a known phenomenon. A similar trend was observed in the succeeding period (29-32 weeks) also. However, the positive genetic as well as phenotypic associations observed (limited in validity due to high standard errors) irrespective of generations in the later periods (P3 and P4), revealed that the antagonizing effect of age at sexual maturity on egg production is not much pronounced in the periods closer to 40 weeks of age. This is a possible situation because the egg production cycle of the flock is established by these stages, thus causing all the birds in the flock to express their full production potential uniformly without depending on the favorable effect of early maturity.

The less precision of the estimates could be due to the possibility that association involving the two traits, viz., independent part records and age at sexual maturity, may not conform to the requirement of a normal distribution (due to sampling error) on which assumption, data are usually subjected to analysis.

It appears from these findings that in order to improve egg production at 40 weeks of age, selection for pullets with early sexual maturity based on independent part records may be practiced at first or second periods (25-32 weeks) to bring about expected results at the genetic level. This is apparent in the lower magnitudes of phenotypic correlations when compared to that of genetic correlations. Therefore, more care would have to be given in the form of appropriate managerial practices and nutritional principles at this stage (25 to 32 weeks of age).

5.4.10.2 Age at sexual maturity (ASM) and cumulative segments

The strong negative associations between various cumulative part records and age at sexual maturity (Table 4.42) at genetic and phenotypic levels in both the generations, reinstates the possibility of improving EP40 by selection of pullets reaching maturity earlier. As the length of the production period increased, the magnitude of association with age at sexual maturity decreased. As a result, the effect of age at sexual maturity is
more pronounced on early part records than later ones, the reason being variance and covariance estimates get decreased due to variations in age at sexual maturity, as part period become longer.

The reports of Flock (1975), Ayyagari (1979), Verma et al. (1984), Mishra et al. (1992) and Mallikarjuna (1998) indicate similar trends in layer type chicken. No reports of the present type were available in meat type chicken for making effective comparisons.

5.4.11 Body weight at sexual maturity and Segments of egg production to 40 weeks of age

5.4.11.1 Body weight at sexual maturity and Independent segments

A perusal of Table 4.43 indicated that body weight at sexual maturity was found to be moderately and reliably associated genetically with the second independent period (29-32 weeks of age) of egg production in S9 generation. The negative relationship suggested that if the body weight at sexual maturity was not kept optimum, the peak egg production that is usually around 32-33 weeks of age in the strain is likely to deteriorate to a considerable extent. This reinstated the need for adoption of restricted feeding in the flock to arrive at an optimum body weight at first egg. The phenotypic correlations were generally undependable in S9 except the one with P1 while those in S10 generation were significant (P≤0.05). In all the cases, phenotypic estimates remained lower than the genetic ones indicating good genetic control over the associations.

5.4.11.2 Body weight at sexual maturity and cumulative segments

Table 4.43 indicated the genetic associations between cumulative part records and body weight at sexual maturity in both the generations to be unreliable. The low precision of the estimates could be due to the possibility that association involving the two traits, viz., cumulative part records and body weight at sexual maturity, may not conform to the requirement of a normal distribution (due to sampling error) on which assumption, data are usually subjected to analysis. However, the phenotypic correlations in both the generations were low and significant (P≤0.05) and they were generally lower in magnitude than their genetic counterparts indicating good genetic control over the associations.

5.5 RESPONSE TO SELECTION
Direct response in the primary trait (BW5) and the correlated responses in secondary traits to mass selection in S9 and S10 generations of PB2 strain were evaluated in the present study.

5.5.1 Effective population size and rate of inbreeding

The trend in response to selection per generation is dependent to a certain extent on the level of inbreeding in the breeding population. The amount of inbreeding would in turn depend on the size of the population, the effective number of parents as governed by the process of natural selection and the system of mating.

From Table 4.44, it was apparent that almost similar numbers of male and female parents per generation were separately utilized to raise the replacement progeny. Since care was also taken to avoid close inbreeding by tracing the pedigree of individuals allotted for mating to the two immediate preceding generations, the rate of increase in inbreeding coefficient estimated was at a low level (0.002) and there was no substantial increase in it over generations in spite of the closed flock breeding structure of the population. This would suggest that progress from selection was not hampered by depletion of variance due to possible inbreeding.

References to effective number of breeders and its impact on the level of inbreeding are borne by the reports of Gowe et al. (1959), King et al. (1959) and Nordskog et al. (1967) in conjunction with the maintenance of suitable control populations in poultry.

5.5.2 Selection Differential

5.5.2.1 Selection differential in the primary trait

The expected and effective selection differentials in the primary trait (BW5), worked out separately for each of the generations and the sexes are presented in Table 4.45.

The intensity of selection in S9 generation for each of the sexes and combined sexes was higher than that in S8 generation. This could well be attributed to the higher selection differential in S9 compared to S8 generation.

The ratio of effective to expected selection differential (combined sexes) for juvenile body weight at five weeks of age were close to unity being, 0.981 in S8 and
0.966 in S9 generations. Falconer (1960), Siegel (1962), Ideta and Seigel (1966), Kinney and Schoffner (1965) have indicated natural selection to be of little importance in the course of artificial selection for body weight. The findings in the study corroborates with the above reports. The proximity of the ratio to unity indicated no possibility of natural selection hindering the pace of genetic improvement in the juvenile body weight over the generations, for which the strain is being artificially selected.

Selection intensity (i) or standardized selection differential is an indicator of the selection pressure applied. This in turn, depends on the variance remaining in the trait during the selection process and the population size. This is of paramount importance, when the population size and number of parents per generation do not vary much (Table 4.44). Selection intensity averaged over generations was 0.868 for males, 0.679 for females and 0.774 for the combined sexes (Table 4.45). Progress from selection is primarily dependent upon ‘i’ and heritability of the trait. The intensity of selection would in turn invariably depend upon the variance of the trait considered for selection. A higher intensity of selection could not be obtained; since the breeding population structure was based on a similar number of sires and dams per generation and the population has undergone selection for more than 20 years. Moreover, being a closed flock, the chances of achieving a higher selection differential in the population was limited, especially so with the females.

5.5.2.2 Indirect selection differential in the secondary traits

Selection differentials in secondary traits as a consequence of direct selection for body weight at five weeks were also estimated (Table 4.46).

The selection differentials for all of the body weights at later stages (BW20, BWSM, BW40) were positive suggesting that direct selection for BW5 would improve the subsequent body weights. The signs of ‘i’ for all the body weights remained the same in both the generations, indicating that the amount of variation in the individuals selected, remained consistent.

The selection differential for age at sexual maturity (ASM) was negative, suggesting that direct selection for BW5 will only lead to reduction in age at first egg. The selection differentials employed for egg production at 40 and 52 weeks of age in both the generations were positive and of considerable magnitude, resulting in high
selection intensities for the trait. The signs of ‘i’ for egg number remained the same in both the generations, indicating that the amount of variation in the individuals selected, remained consistent.

The selection differentials employed for egg weight at 32 weeks were very low in magnitude, negative in S8 generation and positive in S9 generation. Accordingly, the intensities for the trait in both the generations were of opposite signs, suggesting that there was much fluctuation in the amount of variation in the individuals selected as parents to be, as far as the trait was concerned. Same reason could be attributed to the low and negative ‘i’ for EW40 in the S9 generation.

In general, the magnitude of selection differential and selection intensity showed a declining trend from S8 to S9 generations for all the traits. The sign of ‘i’ was consistent over the generations for all the traits except egg weight at 32 weeks of age.

The ratio of effective to expected selection differentials for some of the reproductive traits deviated considerably from unity in S8 generation (Table 4.46) indicating some effect of natural selection on artificial selection. This is because the expected selection differential includes the joint effect of artificial and natural selection. However, the proximity of the ratio to unity in S9 generation was suggestive of natural selection being not a source interfering with artificial selection in the concerned generation.

5.5.3 Observed response to selection

5.5.3.1 Direct response in primary trait

The direct response in body weight at five weeks of age observed in the dam line (Table 4.47) revealed a considerable improvement in the trait over the generations. The responses varied between the sexes within and between generations, due to varying magnitudes of selection intensities applied and different heritability estimates.

The Least squares mean and the computed observed responses for body weight at five weeks of age indicated that mass selection yielded a positive response in both the sexes. The positive responses in both the generations pointed out the existence of most favorable environmental factors conducive enough to allow the full expression of the inherent capacity of the individual birds.
The observed response in many instances may be confounded with environmental effects inhibiting the actual genetic variation. It is seldom possible to have a constant environment over a long period of time and generation means remain confounded with the environmental effect. This makes it difficult to assess the effectiveness of selection and to know how much of improvement is due to selection and how much due to progressive change in environment. In order to circumvent this difficulty and to measure the environmental trend during the course of selection, use of a random bred control population was suggested by King et al. (1959) and Gowe et al. (1959).

The genetic expression of combined hatches of PB2, observed as a deviation from the contemporary control population (Table 4.49) indicated a negative trend (-56.96) in S9 generation followed by a positive response (+227.88) in S10 generation. However, the deviation of first hatch of PB2 from the contemporary control was a positive response in both the generations and therefore the average genetic response was in favor of PB2 irrespective of single hatch or combined hatches at the end of two generations. This suggested that the high magnitudes of positive observed response in the primary trait appear to be due to the favorable environmental conditions in the form of good nutrition and management.

There are sufficient evidences in literature supporting that mass selection was effective to bring about improvement in juvenile body weight in meat type chicken (Jaap et al., 1962; Maloney and Gilberth, 1967; Siegel, 1962; Ideta and Seigel, 1966; Kinney and Schoffner, 1967; Kuruvilla, 1979; Murthy and Khosravinia, 2005; Reddy et al., 2005). The results obtained in the study are in conformity with the above reports. Differences in the magnitude of the responses as observed in the study might be attributed to the genetic architecture of the population studied, heritability estimates of the trait, the selection intensity applied, different managerial practices followed and such other factors.

It may be borne in mind that the control populations were maintained only for the first hatch and not for every single hatch in all the generations. They were also not derived from the same leading strains and were of not a population size comparable with the strain under study. The environmental effects which are confounded with the phenotypic responses of those hatches without a control, might lead to the over
estimation of the genetic responses. The comparison of observed response of a population of combined hatches, with the genetic responses derived as deviation from the control population of a single hatch, might therefore become biased and inaccurate. Hence, it is advisable to maintain a control line of similar genetic make-up and population size with every hatch in each generation to assess accurately the effect of artificial selection, devoid of any environmental effects.

5.5.3.2 Indirect response in secondary traits

Indirect responses for the unselected traits are presented in Table 4.47 and the genetic expression of PB2 measured as deviations from the control population are depicted in Table.4.49.

1. Body weights (BW20, BWSM, BW40)

Existence of positive relationship between BW5 and body weights at 20 (BW20), 40 (BW40) weeks of age and at sexual maturity (BWSM) resulted in positive responses in these traits as per expectations in the S9 generation (Table 4.48). However, S10 generation showed a negative response for BW20, BWSM and BW40, which could be attributed to the more effective restricted feeding, adopted at the grower stage to attain optimum body weight at 20 weeks of age. The observance of decline in BW20 towards the optimum is in the desirable direction for a broiler dam line since it leads to better persistency of egg production.

The genetic response of combined hatches of PB2, expressed as deviation from the control also showed the expected trend of increase in these body weights in S9 and S10 generation. This indicated that the birds had a genetic tendency to gain heavily by 20 weeks and afterwards, which would result in undesirable implications on their production performance at later stages. Hence, the adoption of restricted feeding in S10 generation is appreciable because of which there has been considerable reduction in the weight gain.

2. Age at sexual maturity (ASM)

The birds of S9 generation matured early by 12.05 days and the genetic response of combined hatches measured as deviation from the control also favoured a reduction of 18.0 days. Similarly, in S10 generation, the genetic response was a reduction of 5 days, but a delay of 13.13 days was observed. This reverse trend in S10, leading to a delay in age at first egg, could have been the outcome of substantial decrease in BW20 resulting
from the restricted feeding program. The average observed response over two generations was a delay by 0.54 days. The deviation of first hatch of PB2 from the contemporary control was also a reduction in ASM in both generations.

The reduction in BW20 and the consequent delay in ASM would be beneficial to broiler breeder populations (Aseefa Hagos, 1988; Prashanth Kumar, 2005).

3. Egg weights (EW32 & EW40)

The findings with respect to the observed response in ASM could further be illustrated with respect to the indirect response in egg weight. In S9, when ASM was earlier, eggs were of smaller size due to the positive genetic correlation between ASM and EW32. This was further evident from the negative genetic response of combined hatches of S9 measured as deviation from the control, indicating that the genetic causes favoured a slight reduction in egg weight at 32 weeks. The genetic response in combined hatches compared to control also indicated decrease in egg weight. However, the decline in BW20 and the consequent delayed age at sexual maturity, contributed to heavier eggs at 32 weeks (EW32) in S10, supported by the positive genetic response in comparison to the control.

In the case of egg weight at 40 weeks (EW40), a marginal and insignificant decline was observed in S10. This might have resulted from the negligible negative selection differential (-0.04) employed indirectly for this trait, owing to the less variation in the individuals selected in S8 generation. The genetic response of combined hatches when compared to the control was also a reduction in the egg weight.

4. Egg production up to 40 and 52 weeks of age (EP40 and EP52)

The positive response of 7.64 eggs in S9 was followed by a reduction of 8.67 eggs in S10. This decline in egg number at 40 weeks of age, in spite of the reasonable positive selection intensities employed for egg production, could be attributed to the decline in BW20 and the subsequent delay in ASM, occurred as a sequel to the feed restriction in S10. The declining trend has originated from environmental effects (restricted feeding) as revealed by the genetic response of combined hatches and first hatch expressed as deviation from the control, indicating a gain in egg number in PB2.

The decline in egg number to 40 and 52 weeks of age may not be of much concern, since from Table 4.18, it can be understood that the restricted-fed birds (S10)
have remained in production for a longer time and have contributed more eggs towards the late phase (beyond 52 weeks) compared to the previous generation. This finding is appreciable from the point of view of economics of broiler breeding in terms of reduction in feed cost and increased productive life of a dam line.

The observed responses in egg weights and egg production to 40 weeks of age in the present study are comparable with the reports of Reddy et al. (2005b) in the same strain at a different location.

5.5.4 Realized response

As against the observed responses (direct and indirect) studied hitherto, the realized gains furnished in Tables 4.50a and 4.50b depicted non-conformity of these estimates. The observed responses for BW5 were manifold compared to the realized gains, irrespective of either generations/ sexes within a strain. This was because of favorable environmental factors besides the genotype – environment interactions.

While the trends of both realized and observed responses in the primary trait (BW5) and the egg weight (32 weeks) was similar, the magnitudes differed, possibly because of the different methodologies adopted in estimating them. However, for the remaining traits, the trend of observed and realized responses differed between the generations due to the effect of restricted feeding.

The ratios of effective to expected selection differentials in S8 (Table 4.46) for all the reproduction traits were found to be slightly away from unity. In this context, natural selection might have interfered with the artificial selection in dams of S8, with respect to the selection differentials. Even though the observed responses for the secondary traits in S9 generation were much higher than the corresponding realized gains, they looked inflated due to the confounded favorable environmental effects that must have helped the surviving pullets to withstand the antagonizing effect of natural selection on their subsequent performance.

It would be evident from this study that in almost all instances, the observed responses were higher than the realized responses. Such discrepancies in selection experiments between realized and observed gains have also been reported by a number of workers (Kuruvilla, 1979; Thiagasundaram, 1984; Rath, 1986; Srivastava et al., 1989; Leo, 1991 and Reddy et al., 2005).
5.5.5. Expected Correlated response

The study of correlated characters is of interest for two important reasons: Firstly, in connection with genetic cause of correlation, through pleiotropic action of genes; and secondly, in connection with changes brought about by selection. Correlated responses in secondary traits occur as a sequel to direct selection. Their magnitude depends on the nature of genetic relationship and the phenotypic standard deviation, besides heritability.

1. Body weight at 20 weeks (BW20)

A positive correlated response lower than the observed response was obtained for pullet body weight at 20 weeks of age in S9 generation. Whereas, in S10 generation, the observed response (a decline) and correlated response (a gain) were of opposite signs under the influence of restricted feeding. The average correlated response over two generations remained positive in both the generations in spite of the restricted feeding. The managerial, nutritional and other miscellaneous environmental factors seemed ideal to enable the pullets to express their genetic potentiality.

The expected correlated gain in BW20 on direct selection to BW5 was considerable but the proportionate gain in egg production up to 40 and 52 weeks of age (EP40 and EP52) was not commendable. Since, BW20 and egg production at any stage were positively related (Table 4.35 and 4.36), it appeared that BW20 in S9 generation, being on the higher side and leading to early maturity, was not optimum to achieve a proportionate improvement in EP40. Whereas, in S10 generation, in spite of the lowered BW20 and subsequent delayed maturity, the total egg production beyond 52 weeks remained the same justifying the adoption of restricted feeding to optimize BW20 in the population.

2. Age at sexual maturity (ASM)

A negative correlated response lower than the observed response and realized gain was obtained for age at sexual maturity in S9 generation. Whereas, in S10 generation, the observed response (a delayed maturity) and correlated response (an early maturity) were of opposite signs under the influence of restricted feeding.

The lower correlated response in ASM compared to the realized response, together with the negligible improvement in the egg production (EP40) point out that the age at first egg is not optimum to exploit the full production potential of the strain in S9
generation. The pullets can be prepared to attain an early maturity; if an artificial light regime is practiced along with the restricted feeding programme intended to optimize BW20. This would in turn increase the number of days in production thereby making each dam to contribute more number of eggs.

3. **Body weight at Sexual maturity (BWSM)**

Similar trends as in BW20 were observed for all types of responses for body weight at sexual maturity in both the generations. Since, BWSM and egg production at any stage were positively related (Table 4.35 and 4.36) and only a minimum body weight is to be achieved to initiate egg production, a commendable reduction in the trait was attained in S10 generation through restricted feeding.

4. **Egg weights at 32 and 40 weeks of age**

On direct selection for body weight at five weeks (BW5), the egg weights (EW32 and EW40) possessed a genetic predisposition towards improvement in both the generations, in terms of the secondary correlated responses presented in Table 4.51. However, the observed and realized responses for EW32 showed a marginal and insignificant reduction in S9 due to the less genetic variability and a negative selection differential existed in S8 generation. The declining trend of realized response in S10, though very marginal, was overcome through the slight increase in egg weight as a result of the delayed sexual maturity under restricted feeding. The negative realized response in EW40 also was marginal (close to zero) and insignificant, indicating the stable maintenance of egg weights in the population.

5. **Body weight at 40 weeks**

The correlated responses were lower than the observed response in S9 generation. Whereas, in S10 generation, the observed response (a decline) and correlated response (a gain) were of opposite signs under the influence of restricted feeding. The average correlated response over two generations was positive. This was similar to BWSM and was not unexpected because the latter two traits are the expression of the same trait, but measured at different ages and also they are positively related due to pleiotropy.

6. **Egg production up to 40 and 52 weeks of age (EP40 and EP52)**

The increase of 0.234 (S9) and 0.218 (S10) eggs for EP40 and 0.297 (S9) and 0.110 (S10) eggs for EP52 may be partly attributed to the second stage selection for the
trait in each generation as dams which were laying more number of eggs had higher opportunity to leave more progeny. The results of positive genetic correlation between body weight at five weeks of age (the primary trait) and the positive correlated gain in egg production to 40 and 52 weeks, when selection is operated on weight at five weeks, suggested that multi-stage mass selection currently followed in the strain could be carried out for a few more generations to have simultaneous improvement in both the traits. This was however subject to maintenance of standard and uniform environmental conditions like restricted feeding at the grower stage to arrive at a balance between body weight profile and production performance of the dam line pullets.

Several workers have observed a decline in egg production due to selection for high juvenile body weight in meat type chicken on account of their negative relationship as contrary to the findings of the present study (Ideta and Siegel, 1966; Melony et al., 1967; Reddy and Siegel, 1977; and Marks, 1983).

The positive correlated responses in body weights in the present study are contrary to those reported by Reddy et al. (2005b) in the same strain at a different location, which showed a negative trend in these traits, over the generations. Similar discrepancy was observed in the response in EW32 also, the trait showing an improving tendency in the current study and a decline in the former. However, the reducing trend in ASM and the positive response in EW40 and EP40 are comparable with the same report of Reddy et al. (2005b), even though the magnitudes of response differ. These discrepancies between the responses of the same strain maintained at different locations could be attributed to the differences between the populations with respect to the number of generations of selection, the genetic variability of the population, the selection differential and selection intensities applied and the possible genotype-environment interactions.

In general, there was poor agreement between the observed indirect and expected correlated responses of secondary traits. The probable reason for the higher observed indirect response might be environmental and chance factors. This in turn, is because of the different formulae from which both the observed and expected correlated responses are estimated. While the former includes genetic, environmental plus the possible interaction between the two, the latter is comprised of the chief causes of variability.
Dickerson (1955) has suggested that the non-additive gene effects confounded with the estimates of genetic and phenotypic parameters would also have become a consistent cause of over-estimation of expected correlated response to mass selection.

5.6 PATH COEFFICIENT ANALYSIS

From the estimates of the phenotypic correlations furnished in Table 4.40, it was evident that egg production up to 40 weeks of age was positively correlated with different independent segmented periods of egg production as indicated by the significantly high estimates. The breeder would naturally be misled to understand that phenotypic selection for any of these four early segments of egg production would be expected to improve egg production to 40 weeks of age. Based on these findings, a poultry breeder would be in a dilemma as to decide, which would be the specific stage most preferable for selection to be exercised, such that maximum egg production to 40 weeks may be obtained. However, these correlations do not exactly account for the total variation in egg production to 40 weeks of age, since it is true that each segmented part of egg production has variable influence on egg production up to 40 weeks of age. Hence, when the relationship of EP40 is considered with more than two periods at a time, a complex situation arises due to the interdependence among the segmented parts of egg production. To solve these intricacies of relationship, path coefficient analysis was adopted to partition the total correlation to direct and indirect influences of the auxiliary segmented parts of egg production.

The simple phenotypic correlations observed between the independent part records at earlier ages with that of EP40 (i.e., the total correlation) was the result of direct and also indirect relationships. Direct relationship of any trait with EP40 was attributed due to that trait alone, while the indirect relationship was due to its effect through the other related traits. To untangle the masked indirect effects and also to know the real nature of the direct effects, path analysis offers a solution to examine critically the specific forces acting to produce a given correlation and measure the relative importance of each causal factor.

Considering the egg production during the first period (25 - 28 weeks) either in terms of direct effects (0.6311(S9), 0.6210 (S10) and 0.690 (pooled)) or in terms of indirect
effects, which ranged from 0.0065 (P4) to 0.0621 (P2) in S9 generation, 0.0194 (P3) to 0.1117 (P2) in S10 generation and 0.0255 (P4) to 0.1505 (P2) when pooled over generations (Tables 4.52 to 4.54), it could be pointed out that egg production during 25 - 28 weeks of age had a major influence on egg production to 40 weeks of age. Next in the order of importance was egg production during 29-32 weeks of age (P2), which had profound influence directly as well as indirectly. Egg production during the last two segmented periods (P3 and P4) from 33-40 weeks of age had comparatively lesser influence directly and indirectly on EP40. Their high phenotypic correlation with EP40 was the result of indirect influences through the first two segmented parts of egg production (P1 and P2) during 25-32 weeks of age. Further, residual effects (Figs. 4.1 to 4.3), which were unaccounted, were shown to have had a reasonable direct influence on egg production to 40 weeks of age.

Considering all these aspects, it could be summarized in general that, though egg production during 25-28 weeks of age (P1) had the highest phenotypic correlations (0.740 in S9, 0.772 in S10 and 0.770 when pooled) with egg production up to 40 weeks of age, this period cannot be considered for selecting the prospective parents phenotypically to improve egg production up to 40 weeks of age. During this period (P1), the number of birds that were in production in the flock was less and showed large variability in egg production, as indicated by the very high coefficient of variation. Therefore, the second period P2, that had the second greatest influence on egg production to 40 weeks, could be recommended for phenotypic selection for improving egg production up to 40 weeks of age. This finding could be further substantiated in the nature of correlated responses. At the same intensity of selection (i = 1), it can be postulated that, one round of direct selection for egg production during 29-32 weeks of age (P2) is expected to improve EP40 by 0.764 eggs and 1.18 eggs as correlated response in S9 and S10 generations, respectively. Whereas, negligible correlated improvements of 0.19 eggs and 0.39 eggs can be obtained in P2 period in respective generations due to direct selection for EP40.

Hence, it is suggested that attempts like an artificial lighting regime should be adopted to facilitate high egg production between 29 and 32 weeks of age and selection pressure be applied so as to meet the stipulated population size of pullets in
production, such that the feasibility of further improving egg production to 40 weeks of age through genetic selection can be made. It can be postulated from Table 4.20 that the maximum number of eggs obtained in any single 28-day (672 hours) independent segment was only 20 eggs, irrespective of the generations. Considering the fact that a time interval of about 26 hours is required for a bird to produce an egg, the full production potential of the birds appeared to be approximately 25 to 26 eggs. Therefore, an increment of 5 to 6 eggs can be expected in each of the second (P2) and third (P3) independent segments, if appropriate managemental measures like artificial lighting schedules are undertaken.

From the results of path analysis, equations of predictive nature specifying the effect (egg production to 40 weeks of age) and causes (independent part records) can be constructed. The equations would be of the following form for S9, S10 generations and pooled generations, based on the direct effects of each part record on the total effect.

1) \[ Y = 0.6311 \text{ (P1)} + 0.2748 \text{ (P2)} + 0.2367 \text{ (P3)} + 0.2414 \text{ (P4)} \] which in the simplified form is \[ Y = 2.67 \text{ (P1)} + 1.16 \text{ (P2)} + \text{P3} + 1.02 \text{ (P4)} \]

2) \[ Y = 0.6210 \text{ (P1)} + 0.3864 \text{ (P2)} + 0.2777 \text{ (P3)} + 0.2879 \text{ (P4)} \] which in the simplified form is \[ Y = 2.24 \text{ (P1)} + 1.39 \text{ (P2)} + \text{P3} + 1.04 \text{ (P4)} \]

3) \[ Y = 0.6901 \text{ (P1)} + 0.2610 \text{ (P2)} + 0.2021 \text{ (P3)} + 0.2301 \text{ (P4)} \] which in the simplified form is \[ Y = 3.42 \text{ (P1)} + 1.29 \text{ (P2)} + \text{P3} + 1.14 \text{ (P4)} \]

where \( Y \) is the egg production up to 40 weeks of age, P1, P2, P3 and P4 are egg production during the periods, 25-28 weeks, 29-32 weeks, 33-36 weeks and 37-40 weeks of age, respectively. On the basis of this kind of index values, best birds can be selected phenotypically based on part records and be used for further breeding for the production of replacement progeny.

**Residual effects**

The medium estimate (0.3575) of residual effects in S9 generation (Fig.4.1) indicated that a part of the total variation observed in egg production up to 40 weeks of age (EP40) was due to such causes not included in the analysis. However, in S10
generation (Fig. 4.2), the residual effects were negligible (0.0001) indicating that the various part records under study could explain most of the total variation observed in egg production to 40 weeks of age. Residual effects of considerable degree (0.4075) in pooled generations (Fig. 4.3) further reinstated that final egg production at 40 weeks of age may not wholly be the result of part records measured at earlier ages. Certain forces still existed to control the expression of this trait. In path coefficient analysis, such a result is not unexpected, when only the phenotypic correlations are utilized.

Conclusions on the study of path coefficient analysis have brought out its application and importance in specifying the real causes of correlation among part records measured at different ages and the relative importance of each of these causes (independent part records). This is unlike the correlation, which simply measures the association between the traits. Another advantage of path analysis lies in its importance in character selection, which should be exercised with great care (Srivastava and Sharma, 1976). Discrepancies between path coefficient analysis and correlation coefficient analysis have also been reported by Bhat (1972) in wheat crop.

The investigations contemplated in the present study on path coefficient analysis of egg production, being a unique attempt on breeder dams of a broiler dam line, lacks many reference to literature reports. However, current findings are in conformity with that of Reddy (1996) in a colored broiler male line, in which the period, 29 – 31 weeks of age, has been identified to be the best stage for the prediction of EP40. However, several workers have pointed out the part term egg production to be dependent on various independent variables such as weight at housing, age at sexual maturity, egg mass and egg weight in layer type birds indicating that appropriate measures need to be undertaken by breeding methodologies for bringing about further improvement in part production (Jayanna, 1980 and Goher et al., 1989).

5.7 STEP REGRESSION ANALYSIS
5.7.1 Prediction of Egg production up to 40 weeks of age (EP40) from independent and cumulative part records, Age and Weight at sexual maturity

5.7.1.1 Independent part records
The results presented in Tables 4.55 and 4.56 indicated improvement in the coefficient of determination ($R^2$) value with addition of each independent variable at each stage of analysis. Though the $R^2$ values improved from 57.6 to 79.8 per cent in S9 generation and 55.3 to 88.8 per cent in S10 generation, at the addition of each variable, the amount of increase after step three was negligible. Therefore, the prediction equations at the third step (which includes the first three part records) are identified as the best ones:

$$Y_3 = 4.191 + 1.593 X_1 + 1.238 X_2 + 1.218 X_3$$

$$Y_3 = 6.055 + 1.085 X_1 + 1.008 X_2 + 1.581 X_3$$

The $R^2$ values of these equations were 79.6 and 88.4 per cent, respectively for S9 and S10 generations. With the addition of ASM, the $R^2$ value further increased slightly to 79.8 and 88.8 per cent, respectively in S9 and S10 generations. BWSM did not make any contribution in either of the generations.

When generations were pooled (Table 4.57), the results indicated improvement in the coefficient of determination ($R^2$) values from 59.9 to 83.0 per cent, at the addition of each independent part record, ASM as well as BWSM. The amount of increase after step three was not much. Therefore, the prediction equation at the third step (which includes the first three part records) is recommended:

$$Y_3 = 7.1450 + 1.387 X_1 + 0.966 X_2 + 1.444 X_3$$

The $R^2$ value of this equation was 82.5 per cent. With the addition of ASM next and later BWSM, the $R^2$ value further increased slightly to 82.9 and finally to 83.0 per cent.

5.7.1.2 Cumulative part records

The results presented in Tables 4.61 and 4.62 indicated increase in the coefficient of determination ($R^2$) value from 93.7 to 94.5 per cent in S9 generation and 92.7 to 94.4 per cent in S10 generation, at the addition of each cumulative part record. The second step of analysis, which included two of the cumulative part records (EP36 and EP32), gave slightly higher $R^2$ values than the first step. But considering the extra labor and time involved in maintaining the data on these two segments separately to obtain only a slightly better accuracy, the equations consisting of a single cumulative part record
(EP36) and with a comparable accuracy, seems to be satisfactory for practical purposes. Therefore, the prediction equations at the first step with $R^2$ values of 93.7 per cent and 92.7 per cent are identified as the best ones, respectively for S9 and S10 generations:

$$Y_1 = 16.140 + 1.004 X_3$$

$$Y_1 = 16.087 + 1.053 X_3$$

When generations were pooled (Table 4.63), there was improvement in the coefficient of determination ($R^2$) values from 92.9 to 94.1 per cent, at the addition of each cumulative part record and ASM. The amount of increase after step two was not much. But due to the reasons mentioned earlier, the prediction equation at the first step (which includes only one of the part records, EP36) with a satisfactory accuracy is recommended:

$$Y_1 = 16.917 + 1.035 X_3$$

The $R^2$ value of this equation was 92.9 per cent. With the addition of P2 further and ASM finally, the $R^2$ value improved slightly to 94.0 per cent and finally to 94.1 per cent.

5.7.2 Prediction of Egg production up to 52 weeks of age (EP52) from independent and cumulative part records, Age and Body weight at sexual maturity

5.7.2.1 Independent part records

The results presented in Tables 4.67 and 4.68 indicated improvement in the coefficient of determination ($R^2$) value with addition of each independent variable at each stage of analysis. The $R^2$ values improved steadily from 38.7 to 68.7 per cent in S9 generation and 28.0 to 71.2 per cent in S10 generation, at the addition of each variable. Therefore, the prediction equations at the fourth step (which includes all the part records) are identified as the best ones:

$$Y_4 = 20.069 + 1.611 X_1 + 1.529 X_2 + 1.117 X_3 + 1.382 X_4$$

$$Y_4 = 4.273 + 1.112 X_1 + 1.462 X_2 + 1.669 X_3 + 1.923 X_4$$

The $R^2$ values of these equations were 68.7 and 71.2 per cent, respectively for S9 and S10 generations. ASM and BWSM did not make any contribution in either of the generations.
When generations were pooled (Table 4.69), the results indicated improvement in the coefficient of determination ($R^2$) values from 33.8 to 70.2 per cent, at the addition of each independent part record. Therefore, the prediction equation at the last step (which includes all the part records) with the similar trend as that of individual generations is recommended:

$$Y_4 = 11.904 + 1.414 X_1 + 1.308 X_2 + 1.420 X_3 + 1.823 X_4$$

The $R^2$ value of this equation was 70.2 per cent.

5.7.2.2 Cumulative part records

The results presented in Tables 4.73 and 4.74 indicated increase in the coefficient of determination ($R^2$) value from 81.9 to 82.9 per cent in S9 generation and 76.3 to 81.4 per cent in S10 generation, at the addition of each cumulative part record and ASM. The first step of analysis with EP40 alone, gave high $R^2$ values of 81.9 per cent and 76.3 per cent respectively, in S9 and S10 generations. The second step of analysis, which included two of the cumulative part records, gave quite higher $R^2$ values than the first step. However, the $R^2$ values improved only slightly with the addition of ASM in the third step. Therefore, considering the ease of computation and the reasonable accuracy, the prediction equations at the first step (only EP40) with $R^2$ values of 81.9 per cent and 76.3 per cent are identified to be the best, respectively for S9 and S10 generations:

$$Y_1 = 36.326 + 1.120 X_4$$
$$Y_1 = 29.757 + 1.235 X_4$$

When generations were pooled (Table 4.75), there was improvement in the coefficient of determination ($R^2$) values from 79.4 to 83.0 per cent, at the addition of each cumulative part record and ASM. The amount of increase after step two was not much. Therefore, following the same trend as in individual generations, the prediction equation at the first step (which includes only EP40) is recommended:

$$Y_1 = 35.081 + 1.149 X_4$$

The $R^2$ value of this equation was 79.4 per cent. With the next addition of EP32 and ASM later, the $R^2$ value further increased slightly to 82.7 per cent and finally to 83.0 per cent.
From the overall results, it can be observed that age at sexual maturity (ASM) and body weight at sexual maturity (BWSM) seldom made any significant contribution to the dependent variable (part term egg production up to 40 / 52 weeks of age). Their standardized partial regression coefficients were non-significant and hence they did not enter the analysis. This could also be attributed to their altered expression under the influence of the restricted feeding practiced during the grower stage. It was also evident that the total egg production up to 40 weeks of age (EP40) had the greatest influence on the later egg production at 52 weeks of age (EP52) when compared to it’s earlier independent or cumulative segments at 28, 32 and 36 weeks of age. This could well be attributable to the fact that EP40 had been the focus of selection for improvement of egg production in the strain, for the past several generations. Overall, the regression analyses in different combinations revealed that the cumulative part records were more reliable and accurate in predicting the egg production up to 40 and 52 weeks of age in comparison to the independent part records.

The $R^2$ values of the recommended prediction equations were comparable with the estimates reported by Singh et al. (1984) and Joshi (2005) for various part records in layer type chicken. The accuracy of these equations were also higher than those reported by Sanjeev Kumar et al. (1997) in Guinea fowl and Sakunthala Devi (2002) in WLH, when the $R^2$ values were compared. The current study, being a unique attempt in broiler breeders, lacks reference to reports on meat type populations to make effective comparisons.

5.8 EGG PRODUCTION CURVES

Different mathematical models have been fitted by earlier investigators to explain egg production based on the data on groups of birds with respect to age. Under such circumstances, the increasing slope of the egg production curve depends on the actual rate of increase in the egg production of the individual hens, as well as on the variation in age at sexual maturity within the group. The present investigation was intended to identify suitable mathematical models to explain average weekly egg production up to 52 weeks of age in PB2 strain and the contemporary Control line.

5.8.1. Identification of suitable egg production models and their efficiency
After the application of mathematical models for the egg production data up to 52 weeks of age in PB2 strain and Control line, the relative efficiency was studied and compared.

The results presented in the Tables 4.79 to 4.84 for PB2 strain and Control line showed that the models, which had high $R^2$ values and low standard error, were in greater agreement with the observed values.

The range of $R^2$ values in the present investigation were in conformity with the findings of various research workers who adopted different models in layer type chicken viz., Mc Nally (1971) for various models (86 to 95 per cent), Gavora et al. (1982) who applied McMillan’s model (97 per cent) and Cason and Britton (1988) who applied Compartmental model (95.23 per cent). The $R^2$ values are also comparable with the findings of Murthy (1998) for Linear and Reciprocal model (71.39 to 91.75 per cent) and second order Hyperbola (83.91 to 96.05 per cent) and Kiran (1998) for various models (85.2 to 96.52 per cent), for egg production in various egg type chicken.

Thomas et al. (1994) and Lal et al. (2003) has identified Quadratic Fit to fit well to the egg production of flocks of egg type chicken. Very high $R^2$ values and accordingly similar best fits for egg production in layer type hens have been reported by Lal et al. (2003) for the same Rational Function identified to be the best fit for PB2 strain and Control Line in the present investigation.

The Tables 4.81 and 4.84 on pooled generations of both the genetic groups showed that the estimated weekly egg production was slightly deviant from the observed values from 19th week to 24th week of age in PB2 and from 24th week to 26th week of age for the Control line for almost all the models fitted. This was not unexpected since it is the outcome of differences in body weights of the birds housed and also differences in age at sexual maturity due to hormonal influences besides differences in age of the birds from different hatches. From 25th week onwards, there was close proximity between the observed and expected values till the attainment of 52 weeks of age.

The deviations of the expected values from the observed values were tested by chi-square for testing the goodness of fit considering the entire production period from 19
to 52 weeks of age. The non-significance of the chi-square values indicated good fit of the models to the data.

A perusal of Tables from 4.79 to 4.81, when judged by the values of coefficient of determination ($R^2$) and Standard errors, for different generations using six mathematical models revealed Rational Function (Model-IV) to be the best fit, very closely followed by Polynomial Fit (Model-III) for the PB2 strain. The other models, Logistic Model (Model-I), MMF Model (Model-II), Quadratic Fit (Model-VI) and Sinusoidal Fit (Model-V), also gave good fits in that order.

Rational Function (Model-IV) which gave the best fit for predictive purposes in individual generations of PB2, failed to fit to the data when generations were pooled. This could be attributed to the large difference in the age at sexual maturity between the generations, which caused a lot of variation in the data so as not to suit the pattern projected by the mathematical model of Rational Function. MMF Model also did not fit to the pooled data. Hence, Rational Function (Model-IV), which gave the best fit with excellent $R^2$ values in individual generations and Polynomial Fit (Model III) identified to be the most suitable for the pooled data, are recommended for the PB2 strain, depending on the type of data adopted.

For the Control line, (Tables from 4.82 to 4.84) when judged by the values of coefficient of determination ($R^2$) and Standard errors, for different generations using six mathematical models, Rational Function (Model-IV) gave the best fit, very closely followed by Polynomial Fit (Model-III). The other models, Quadratic Fit (Model-VI), Sinusoidal Fit (Model-V), Logistic Model (Model-I) and MMF Model (Model-II) also gave good fits in that order.

Thus, Rational Function (Model-IV) and Polynomial Fit (Model-III) were more useful for predictive purposes and being simple, these models could be conveniently adopted for both the strains.

It may be emphasized that pullets of both the genetic groups, at the initiation of production showed more variation and diminished later on exhibiting a linear trend for a few weeks approaching peak production, due to the consistency in egg production cycle per week. From Tables 4.85 and 4.86, it was observed that in both the generations of
PB2, egg production showed only a gradual increase during the initial four weeks of production (until the 22nd and 24th week of age in S9 and S10). This was followed by a sudden increase during the 4th to 5th week of production (23-25 weeks of age). Subsequently, the increases were only marginal up to the completion of 33 weeks of age, when peak productions of 5.25 (S9) and 5.30 (S10) were attained, irrespective of the generations. The increasing trend in average egg production did not persist for long, instead it started diminishing immediately from the next week (34th week) itself, reaching at 4.60 (S9) and 4.72 (S10) at the end of the 40th week of age. By 52nd weeks of age, the average egg production decreased to 3.27 in S9 and 3.08 in S10 generations.

For the Control line, (Tables 4.88 and 4.89), it was observed that in both the generations, the egg production increased gradually during the initial two weeks of production (until the 25th week of age in S9 and S10), followed by a sudden increase that was evident during the 3rd week of production (26 weeks of age). Subsequently, marginal increases were observed up to the completion of 33 weeks of age, when peak productions of 4.84 (S9) and 4.87 (S10) were attained, irrespective of the generations. Thus increase in average HHEP was reasonably maintained (unlike the PB2 strain) up to 37 to 38 weeks of age and thereafter it gradually diminished to 4.84 (S9) and 4.87 (S10) at the end of the 40th week of age. By the 52nd week of age, the average egg production decreased to 3.75 in S9 and 2.76 in S10 generations.

From the overall results, the ranking of the models based on their efficiency in PB2 strain and Control line were different, except for the first two best fitting ones. These models identified to be the best and therefore recommended for predictive purposes irrespective of the strain, are:

1. Model -IV (Rational Function)
2. Model -III (Polynomial Fit of Fourth degree)

CONCLUSIONS

The genetic evaluation of the colored broiler dam line (PB2) in the present investigation revealed that mass selection was effective in improving early body weight at five weeks of age. Since, early body weight at five/six weeks of age was the primary trait for more than ten generations of selection, it can be expected that the population could have exhausted a considerable amount of additive genetic variance. Therefore, the
breeder must attempt to exploit the available resources in a skilful way. The low level of additive genetic variance in juvenile body weight, egg production and egg weights could be the result of effective long-term multi-stage mass selection for early body weight and egg production at 40 weeks of age and the subsequent correlated response in egg weight. Pullets selected for high juvenile body weight on account of their positive phenotypic and genetic predisposition with the production traits like egg number and egg weights indicated no possible deterioration in the concerned traits. This is a desirable situation especially when the birds are reared as female parental line for commercial broiler production. This advantageous situation could well be maintained by the optimization of pullet body weight at 20 weeks of age and age at sexual maturity through restricted feeding and artificial lighting programmes. The practical consideration would be to maintain an Independent Culling Level (ICL) for pullet body weight at 20 weeks of age, which is moderately heritable in the strain. The study has indicated that the body weight at 20 weeks of age, ideal to attain a maximum egg production in the pullets of this colored broiler dam line appeared to be much lower than the target of 2200 g, recommended for commercial broiler breeders. Therefore, it is worthwhile to adopt artificial lighting during their grower and laying stages, to bring about early maturity and high egg number without a further reduction in pullet body weight. An optimal feeding programme based on the level of egg production is also essential for the breeder dams to prevent them from being heavy at mature stage (40 weeks of age), in order to improve the persistency of production. Overall findings suggest that scope existed for further improvement in the persistency of egg production in this female parental line and the pullets can be continued to be selected in two stages: Initially, based on body weight at five weeks of age and finally, on the basis of an index incorporating juvenile body weight and egg number up to 40 weeks of age with restriction on egg weight.