

ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF
POULTRY SCIENCE

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

Genetic and Phenotypic Relationships Between McNally Model Parameters and Egg Production Traits

O.O. Oni¹, B.Y. Abubakar¹, N.I. Dim², O.E. Asiribo³ and I.A. Adeyinka¹

¹National Animal Production Research Institute, Ahmadu Bello University, Shika, Zaria, Nigeria

²Department of Animal Science, Ahmadu Bello University, Zaria, Nigeria

³Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria

Abstract: The monthly egg production data of Rhode Island Red (strain A) and White (strain B) chickens were used to estimate the genetic and phenotypic relationships between egg production traits and curve parameters obtained from fitting the McNally model to 52-wk laying records. A total of 356 and 292 records for strains A and B, respectively, were included in a variance component analysis of a two factor nested classification - dams within sire. The estimates of heritabilities and correlations for production traits were moderate to high, while the values obtained for the curve parameters varied from low to moderate. The estimates of correlations of part-productions with 52-week total were comparatively higher than the values obtained for curve parameters with 52-week total. The low estimates of heritability obtained for curve parameters indicated that it would be better to select on functions of the parameters (such as total production or part-year production), which had higher estimates, rather than individual curve parameters. The high genetic correlation between part-year production and total annual production suggests that selection for the latter based on the former would not diminish genetic progress. The decreased generation interval that would result from selection on part record will probably more than offset the loss in efficiency if records are taken for about half of the full laying year.

Key words: McNally Model Parameters, egg production traits, heritabilities

Introduction

In commercial egg type chicken breeding, the number of important traits has increased over time and emphasis on the traits used in the selection of breeding stocks has varied due to changes in their economic importance. However, the primary trait in layer stock has always been egg production (McMillan *et al.*, 1990). Hence, it is of interest to study the egg production curve and the possible changes that might have occurred in egg production in response to selection.

The common objective of commercial breeders of laying stocks is to increase the number of eggs produced per unit of time. The use of early partial egg records as a selection criterion for improving annual egg production has often been cited as a procedure for obtaining this objective in the shortest possible time (Bohren, 1970). Thus, genetic gain measured against time would be improved as the parental age is reduced (Dickerson and Hazel, 1944). However, reports have indicated that selection based on partial or whole record ignores the possibility that different periods within the record may have dissimilar genetic parameters. Data analyzed by Flock (1977) supported this observation. Similarly, Van Vleck and DooLittle (1964) reported that differences in sexual maturity influence the measure of egg production in the first, and to a lesser extent later months.

Prediction of egg production (and egg size) is necessary for economic projections for laying hens. Mathematical

models provide one means of prediction, but they are sometimes inadequate due to poor extrapolative properties or unreasonable deviations from expectations. Thus, one of the major considerations in choosing a mathematical model of egg production is the ability to predict whole record production from part record. Therefore, with a careful analysis of appropriate data, it should be possible to estimate heritability for the model parameters. This would aid in decision making as to whether it is better to select on individual curve parameters or on functions of the parameters (such as partial or total annual egg production). For example, Timmerans (1973) observed that the parameters in the compartmental model described by Gavora *et al.* (1971) changed substantially with two genetically different strains.

Most of the reports on egg production curves and model fitting appear to have been carried out in the temperate (temperate zone or temperate countries). Even then, very few reports have appeared in literature on genetic aspects for curve parameters. Thus, there is paucity of information on the nature of the egg production curve for layer type chickens bred in tropical areas, where environmental factors are known to influence egg production tremendously. Furthermore, in view of the poor funding of research activities in developing countries, the availability of a large data set for such studies is often precluded. A major drawback to using

small numbers of records for analysis is that the application of the standard statistical procedures to these data is unlikely to estimate the parameters within narrow confidence limits. However, an attempt is made in this paper to provide information on genetic estimates (heritabilities and correlations) for egg production traits and curve parameters in breeder hens reared in a tropical environment.

Materials and Methods

The data used in this study were egg production records of 500 breeder hens each of 2 strains, maintained as a random-bred population of the poultry breeding project, at the National Animal Production Research Institute (NAPRI), Shika, Nigeria. The birds comprised two strains of Rhode Island Red and White breeder hens, termed strains A and B, respectively. The birds were brooded and reared to 18 weeks of age on deep-litter floor pens. Floor space allowed per bird varied from 0.15 to 0.50 m² depending on age of bird. Feed was provided based on body requirement from hatching until point of lay. Birds were fed standard rations formulated at the Institute containing minimum crude protein contents of 18 and 14% for chick and grower diets, respectively. At 18 weeks of age, the birds were randomly placed in individual cages, 500 pullets for each strain. At lay, birds were fed ad-libitum on layer ration containing about 16% crude protein and drinking-water was available at all times.

For each bird, egg production was summarized into 28-day periods, starting from the day the pullet laid its first egg. The individual hen records were grouped by record length in terms of the number of 28-day periods in the first production cycle. Within each group, mean egg production was calculated period by period. Egg production records from point of lay up to the 52nd week of lay were examined in this study.

The model used is the McNally model (modified gamma type), which was expressed as:

$$y_t = a'be^{-ct + dt^{(0.5)}}$$

In the model, the constants a, b, c and d represent the model parameters as defined by the above equation and have their specific significance. Generally, Y_t is the number of eggs laid by an individual or the average number of eggs laid by the group over the period t; b and c represent the rate of increase and decline of production, respectively, in egg production of the group; d is an extra term added by McNally to the gamma type function by Wood (1967) and a is the peak production the group could achieve. The model was fitted to data collected on each strain of breeder hen. To examine the fit of the model to the data used to estimate curve parameters, the functions were transformed to the linear forms as follows;

$$\text{Log } Y_t = \text{Log}^a (\text{Log}_e^a) + b \log_c t - Ct + dt^{1/2}$$

For estimates of genetic parameters, only data from hens which had complete information on the traits measured were considered. Thus, data were obtained from 356 pullets, produced from a single hatch progeny of 17 sires and 132 dams for strain A, and 292 pullets, progeny of 128 dams and 18 sires to compute the various parameters.

The data were analyzed according to the model

$$Y_{ijk} = \mu + S_i + D_j + e_{ijk}$$

where, Y_{ijk} is the record of the Kth hen of the jth dam mated to the ith sire; μ is the population mean; S_i is the effect of the ith sire; D_j is the effect of the jth dam mated to the e_{th} sire; and e_{ijk} is the error term associated with individual observations.

It was further assumed that the S_i, d_j and e_{ijk} were random variables, independently and identically distributed each with zero mean and variances S²m, D²m and E²m, respectively. Thus, components of variance and covariance were estimated by this two-way nested random model using the mixed model least-squares and maximum likelihood computer programme (Harvey, 1990) from which the heritabilities and correlations were derived by full-sib analysis as per Becker (1975).

Results and Discussion

The estimated heritabilities, genetic and phenotypic correlations for production traits and curve parameters are shown in Tables 1-3. The heritability estimates for production traits were moderate, while the values obtained for the curve parameters varied from low to moderate (Table 1). The low to moderate heritability estimates for production traits and curve parameters indicate that intensity of production is low. Hays (1924) observed that four determinants of egg production are important in monthly production records. These determinants are sexual maturity (classically measured as age at first egg or ASM), intensity of production (length of runs of consecutive days on each of which an egg is produced), persistency of production (length of period until production ceases and the bird begins to moult), and occurrence of pauses (periods of consecutive days, usually more than four; during which no eggs are laid). Mortality also affects these production records since a bird is counted as having laid zero eggs after death. Intensity of production enters into all monthly records, and is probably the primary influence on production after the first part-year production until difference in persistency and viability begin to have major effect, and their effect increases in importance with time.

The heritability estimates for the part-production periods increased steadily throughout the annual production

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Table 1: Heritability estimates for production traits and curve parameters in groups of hens

	Strain A (N=356)		Strain B (N=292)	
	$h^2_{s+d} \pm S.E.$	$h^2_s \pm S.E.$	$h^2_{s+d} \pm S.E.$	$h^2_s \pm S.E.$
ASM	0.29±0.108	0.30±0.185	0.42±0.132	0.35 ±0.219
PP16	0.18±0.097	0.29±0.181	0.17±0.109	0.34±0.217
PP20	0.24±0.103	0.23±0.161	0.19±0.112	0.32±0.208
PP24	0.23±0.103	0.26±0.172	0.18±0.111	0.32±0.210
AP52	0.26±0.105	0.29±0.182	0.19±0.111	0.32±0.210
MA	0.16±0.094	0.08±0.109	0.24±0.117	NA
MB	0.16±0.094	0.06±0.102	0.22±0.114	NA
MC	0.167±0.095	0.071±0.107	0.22 ±0.115	NA
MD	0.23±0.102	0.04±0.095	0.32 ±0.124	0.04±0.113

*ASM = age at sexual maturity; PP16, PP20 and PP24 = part-record productions for wks. 16, 20 and 24, respectively; AP52 = Total production for 52 wks; MA, MB, MC and MD = model parameters of McNally. NA, Not available. SE, Standard Error

cycle (Table 1), probably due to increasing genetic variability of persistency and viability during the latter months. This result is in agreement with the findings of Van Vleck and Doolittle (1964). In comparison with estimates from other investigations (Kinney, 1969; Kolstad, 1972a,b), the heritabilities for sexual maturity and egg number were in agreement with those for other populations (Table 1). The heritability estimates obtained for the different production periods are varied. This supports the claim that different production periods within the production record may have different genetic parameters (Flock, 1977; Mur, 1990). Consequently, it was suggested that all parts of the production period should not have equal weights when selection is based on partial record.

The genetic and phenotypic correlations are mostly similar in trends, however, the genetic correlations were generally larger than the phenotypic correlations for all production traits (Table 2). However, estimates of genetic correlations for curve parameters were lower than the phenotypic correlations. The estimates of correlations of part-productions with 52 week total were fairly high. The estimates of correlation between part-production and the annual production were consistently higher than the estimates obtained for sexual maturity with annual production. The estimates of correlations for part-production records that were close together in time were higher compared to records that were further apart. This pattern is much more apparent for the phenotypic correlations. The phenotypic correlations between the part-year production and annual total production increase progressively from the first period. The estimates of genetic correlations of part record with annual production approached unity. This suggests that genetic differences in persistency and viability are more important determinants of variation in total annual production than are differences in intensity. Generally, the genetic correlations are also consistently larger than the phenotypic correlations. This agrees with reports of other workers who have also made similar observations (Lerner and Cruden, 1948; Van Vleck and Doolittle, 1964). Low estimates of heritability are likely to be

associated with fluctuating estimates of genetic correlations. It should be noted that the estimates from sire components of variance were mostly larger than the estimates from the pooled estimates of sire and dam components. Usually, h^2_{s+d} estimates are larger than h^2_s since h^2_s is expected to be less biased than h^2_{s+d} because of the confounding of maternal effects or dominance variance in the hierarchical mating structure. However, there are frequent exceptions that probably indicate the influence of sex-linked genes on the traits concerned.

The estimates of correlation between sexual maturity (ASM) and curve parameters C and D were negative for strain A, but positive for strain B. Similarly, the estimates of genetic correlation between part production periods, annual production and curve parameters C and D were positive in strain A but negative in strain B. However, for phenotypic correlation, the estimates were negative in both strains. On the other hand, the correlation between curve parameters A and B with ASM was positive in strain A but negative in strain B. Also, as observed with curve parameters C and D, the genetic correlations between part-production, annual production and parameters A and B were negative in strain A but positive in strain B. The differences observed in the signs of the relationship between ASM, egg production and curve parameters in the two strains probably indicate strain difference and are apparently characteristic of the production curve for each strain. The heritability estimate obtained for the curve parameters appeared quite low. However, since there are moderate to high genetic correlations between the curve parameter 'a' and production traits, coupled with the ability of the model to predict full production from partial records, the model will be useful as an added tool in selection programmes for egg production in poultry.

Differences in sexual maturity influenced the measures of egg production in the first, and to lesser extent, in later months as evidenced by the progressive decline in correlation estimates between ASM and part-productions and annual productions. However, the

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Table 2: Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations for production traits and model parameters of McNally in strain A

	ASM	PP16	PP20	PP24	AP52	MA	MB	MC	MD
ASM									
PP16	-0.40								
PP20	-0.41	0.96							
PP24	-0.41	0.93	0.98						
AP52	-0.40	0.77	0.80	0.83					
MA	0.06	0.06	0.06	0.05	0.13				
MB	0.09	-0.01	0.13	0.01	0.07	0.97			
MC	-0.07	-0.01	-0.02	-0.01	-0.10	-0.99	-0.98		
MD	-0.04	-0.02	-0.03	-0.02	-0.14	-0.96	-0.93	0.96	

*ASM = age at sexual maturity; PP16, PP20 and PP24 = part-record productions for wks. 16, 20 and 24, respectively; AP52 = Total production for 52 wks; MA, MB, MC and MD = model parameters of McNally

Table 3: Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations for production traits and model parameters of McNally in strain B.

	ASM	PP16	PP20	PP24	AP52	MA	MB	MC	MD
ASM									
PP16	-0.38								
PP20	-0.4	0.96							
PP24	-0.35	0.92	0.98						
AP52	-0.29	0.79	0.84	0.87					
MA	-0.16	0.23	0.21	0.17	0.15				
MB	-0.12	0.17	0.17	0.14	0.11	0.95			
MC	-0.14	-0.18	-0.16	-0.13	-0.11	0.98	-0.96		
MD	0.13	-0.13	-0.11	-0.07	-0.09	-0.92	-0.87	0.92	

*ASM = age sexual maturity; PP16, PP20 and PP24, = part record productions for wk 16, 20 and 24 respectively; AP52 = Total production for 52 weeks; MA, MB, MC, and MD = model parameters of McNally.

medium to high correlations of ASM with part-production records and annual production suggest that the separate measurement of sexual maturity may be useful in supplementing selection from part records. Maternal effects appear important in describing differences in reaching complete sexual maturity and persistency of production (Van Vleck and DooLittle, 1964).

The relative genetic gain to be obtained by selection on the basis of part record can now be discussed. The common objective of commercial breeders of laying stock is to increase the number of eggs produced per unit of time. The use of early partial egg records as a selection criterion for improving annual egg has often been cited as a procedure for obtaining this objective in the shortest time (Bohren, 1970). It has been shown (Lerner and Cruden, 1948) that because of high genetic correlation between part year production and total annual production, selection for the latter based on the former would not diminish genetic progress as compared to selection based on complete records. The generation interval resulting from selection on part-record will probably more than offset the loss in efficiency if records are taken for about half of the full laying year. Thus, the value of using part of the annual egg production for the early selection of superior sire and dam lines in chicken has been widely accepted. This was confirmed by the results obtained by Van Vleck and DooLittle (1964). They reported that if cumulative records of not more than five or six months are used in conjunction with a supplemental measure of ASM. The

relative efficiency of selection on part-records increases rapidly. This finding agrees with the results obtained by Lerner and Dempster (1956) who concluded that pullet breeding is a practical and desirable procedure in programmes of combined family and individual selection for egg production. The classical approach to the breeding of superior animals was based on phenotype variations observed among and between animals. Phenotypic variation is however, a composite of both environmental and genetic variation. Therefore, with the use of prediction models, there may be a great variety of genetic variations of a completely different nature, which may reflect accurately the genetic differences and productive efficiency between individuals.

It appears from the results obtained that selection for total production based on part-year record may not be satisfactory unless the period chosen is one in the latter part of the laying year. Furthermore, selection on functions of curve parameters seems more reliable than using the individual curve parameters although the usefulness of the mathematical model to predict full-year production from part record cannot be over-emphasized.

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