SHORT TERM RESPONSE TO SELECTION IN LAYER TYPE CHICKENS

BY

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CERTIFICATION

This thesis entitled "**SHORT TERM RESPONSE TO SELECTION IN LAYER TYPE CHICKENS**" by Isaac Adetunji Adeyinka meets the regulations governing the degree of doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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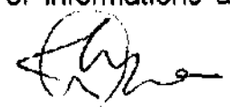
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Isaac Adetunji ADEYINKA

ABSTRACT

The objectives of this study were to estimate response to selection after five generations of selection for egg production to 280 days and to estimate the genetic and phenotypic parameters for egg production traits in layer type chickens under selection.

Data on part year egg production of chickens were used in this study. The chickens were grouped into selected and control within each strain of male and female lines. Response to selection in five generations was calculated for male and female lines. Effective parents for both lines were also calculated using two methods of estimation. The traits considered in the estimation of response to selection and genetic parameters were egg number, age at sexual maturity, average egg weight, body weight at 40 weeks, eggmass to 280 days and rate of lay.

Direct genetic response to selection in part year egg number was higher in the female line than in the male line. There was little or no genetic response in the male line population. This was only 0.41 egg per generation. The value for the female line was 3.4 eggs for the genetic response. From these results, it could be concluded that selection had teen effective in improving the part year egg production in the female line but not in the male line.

Correlated responses in age at sexual maturity, egg weight, egg mass, rate of lay and body weight at 40 weeks were also calculated. In the female line, the correlated response in age at sexual maturity as a result of direct selection

for egg production to 280 days was negative. This was however positive in the male line. Similarly, the correlated response in the rate of lay was positive in the female line and negative in the male line. In fact, in the male line except the body weight at 40 weeks, which showed a positive correlated response of 34g per year, all other traits considered in this study showed a negative correlated response to selection for egg number to 280days. However, in the female line, there was a negative correlated response in the body weight due to selection for increased egg number to 280days. There was a reduction of 0.89g per year in egg weight due to selection for increase in egg number. The correlated genotypic responses in eggmass and rate of lay were very low.

Genetic parameters were pooled over the five-year study period and also estimated after correcting the data for hatch effects. The estimates of heritability and correlations varied from low to high depending on the traits under consideration. The pooled heritability estimates were 0.18, 0.15, 0.24, 0.16, 0.09 and for age at sexual maturity (ASM), egg number (EGGNO), egg weight (EWTAV), body weight at 40 weeks (BWT40), rate of lay (RATE) and egg mass (EGGMASS) respectively among the male line under selection. The corresponding values were 0.20, 0.16, 0.29, 0.21, 0.10 and 0.17 for the female line. The standard errors associated with these estimates were very low which is an indication of their reliability.

The pooled genotypic correlations were also computed. Age at sexual maturity was highly negatively correlated with egg production to 280 days in both lines. The pooled genotypic correlation of egg production with eggmass and rate

TABLE OF CONTENTS

Page

TITLE PAGE i

CERTIFICATION ii

DECLARATION iii

DEDICATION iv

ACKNOWLEDGEMENT v

ABSTRACT vii

TABLE OF CONTENTS x

LIST OF TABLES xiv

LIST OF FIGURES xviii

CHAPTER 1 1

INTRODUCTION 1

CHAPTER 2 4

LITERATURE REVIEW 4

2.0 The domestic chickens: an Overview. 4

2.1 Origin of domestic chickens. 4

2.2 Distribution 4

2.3 History of breeding. 6

2.4 Basis of selection 7

2.5 Principle for the construction of the selection indexes 10

2.6 Selection methods. 11

Page

2.7 Primary trait of economic importance 13

2.8 Response to selection 14

2.8.1 Direct response 14

2.8.2 Correlated responses 15

2.8.3 Egg weight 16

2.8.2 Body weight 17

2.9 GENETIC PARAMETERS 17

2.9.1 Egg number 17

2.9.2 Egg weight 19

2.9.3 Age at sexual maturity 20

2.9.4 Body weight 20

2.10 CORRELATIONS 21

CHAPTER 3 26

MATERIALS AND METHODS 26

3.1 The location of the project 26

3.2 Synthesis of common base population 26

3.3 Mating procedure 31

3.4 Data 31

3.5 Numbers of experimental animals. 33

3.6 Hatching procedure 33

3.7 Environment of selection lines and control 34

3.7.1 Housing 34

Page

3.7.2 Nutrition 35

3.7.3 Recording of data 36

3.7.4 Traits used 36

3.8 Analytical procedure 37

3.8.1 Data transformation 37

3.8.2 Estimation of genetic parameter 38

3.8.3 Estimation of correlations 40

3.8.4 Estimating expected and realized response to selection 42

3.8.5 Estimation of expected and realized responses to selection for primary traits under selection 42

3.8.6 Multilocational of the commercial layer resulting from the selection experiment 47

CHAPTER 4 49

RESULTS 49

4.1 Effective population size and inbreeding 49

4.2 Variance components 49

4.3 Maternal effects 50

4.4 Heritability estimates 51

4.5 Genetic correlation 85

4.6 Genetic parameter estimation using one way analysis of variance model ... 86

4.7 Variance components 87

4.8 Selection differential 87

Page

4.9 Responses of egg number (primary trait) to selection 88

4.10 Correlated responses 89

CHAPTER 5 90

DISCUSSION 90

5.0 Effective population 90

5.1 Selection response 91

5.2 Correlated responses 94

5.3 Genetic parameters 98

5.4 Heritability estimates 98

5.5 Multi-locational performance of commercial layers 101

CHAPTER 6 102

CONCLUSION 102

REFERENCES 105

LIST OF TABLES

Page

Table 1 Mating arrangement between cocks and hens of the two strains of grandparent stock 27

Table 2: A diallel cross arrangement among F_1 cocks and hens of different strains within sire and dam lines 28

Table 3: Experimental chick, grower, layer and breeder rations 36

Table 4. Effective number of sires, dams and parents and expected inbreeding for birds reaching breeding age 53

Table 5. Average performance by generation, population and traits of male line selected for improved egg production 54

Table 6. Average performance by generation, population and traits of female line selected for improved egg production 55

Table 7 Variance component of male line by year 55

Table 8. Maternal effect (+) and sex linkage (-) in male line 57

Table 9. Maternal effect (+) and sex linkage (-) as % of total variance in male line 57

Table 10. Variance components by traits, generation using sire information only in male line 58

Table 11 Variance components as % of total variance by year in the male line ... 59

Table 12. Variance components as % of total variance due to sire group in the male line 60

Table 13. Variance components by year of female line selected for improved egg production 61

Table 14. Variance components as % of total variance by year in the female line selected for improved egg number..... 62

Table 15 Maternal effect (+) and sex linkage (-) of female line selected for improved egg number 63

Table 16. Maternal effect (+) or sex linkage (-) as % of total variance in female line selected for improved egg number 63

Table 17 Variance component by traits, generation and se from paternal half-sib model in the female line selected for improved egg number..... 64

Table 18. Variance components as % of total variance due to sire group in the female line selected for improved egg number 65

Table 19 Heritability estimate from sire, dam and sire+dam components by year, traits and sources of variation in the male line selected for improved egg number 66

Table 20. Heritability estimate from components of variance by year, traits and sources of variation in female line selected for improved egg number 67

Table 21 Yearly genetic correlation between Egg number and other traits in female line (from sire+dam components of variance) selected for improved egg number 68

Table 22 Yearly genetic correlation between Egg number and other traits in male line (from sire+dam components of variance) selected for

improved egg number 68

Table 23 Yearly genetic correlation between egg number and other traits by year from dam components of male line selected for improved egg number 69

Table 24 Yearly genetic correlation between egg number and other traits in female line under selection (from sire component of variance) 69

Table 25 Yearly genetic correlation between egg number and other traits in female line under selection (from dam component of variance) 69

Table 26 Yearly genetic correlation between egg number and other traits in female line under selection (from sire+dam component of variance) 70

Table 27 Yearly genetic, phenotypic and environmental correlation by trait in male line using sire information of other traits with egg number..... 70

Table 28 Yearly heritability estimates in male line based on sire information only. 71

Table 29 Yearly genetic, phenotypic and environmental correlation of other traits with egg number in female line using sire information 72

Table 30 Yearly heritability estimates in female line based on sire information only 73

Table 31 Correlation of egg number with other traits in male line selected for improved egg production 73

Table 32 Correlation of egg number with other traits in Female line selected for improved egg production 74

Table 33 Selection differential of egg number to 280 days 75

Table 34 Estimated genetic and phenotypic change per generation 76

Table 35 Realised response and predicted gain for egg production up to 280 days 76

Table 36 *The expected correlated response per generation* E(CR), *in secondary* traits from selection on egg production to 280 days 77

Table 37 Average performance of the commercial layer resulting from the selection experiment 78

LIST OF FIGURES

Fig. 1 Egg production per generation in selected and control lines 79

Fig. 2 Age at sexual maturity for selected and control lines 80

Fig. 3 Average egg weight for selected and controls lines 81

Fig. 4 Body weight at maturity for selected and control lines 82

Fig. 5 Egg mass to 280 days for selected and control lines 83

Fig. 6 Rate of lay to 280 days for selected and control lines 84

CHAPTER 1

INTRODUCTION

Poultry production in Nigeria has been very popular since the early 1970s'. Poultry were hitherto kept in small flocks as backyard farm enterprise. For example, in the villages of West Africa, the wife may keep a dozen or so chicken. However, commercial poultry production has been on the increase in recent times. Initially, the commercial egg and broiler producer depended mostly on the importation from overseas of exotic commercial day old chicks for most of their production. An improvement over the importation of commercial day old chicks was the establishment of franchised hatchery

Apart from the economy of importation, there is the danger of the introduction of foreign diseases, which may later become endemic. Most of the researches conducted in Nigeria have been nutritional experiments using imported commercial chicks. It is a well known fact that the production of an animal depends on its environment and its genotype. Thus, stocks bred and developed in the country will be more adapted to the environment than the imported stocks. From the point mentioned above, the importance of establishing national breeding stocks that will serve as basis for producing commercial egg type chicks is obvious. One of two options can be adopted for this purpose;

1. Nigerian local chickens can be used as the parent stocks on which selection can be carried out for improved productivity.

2. Importation of four or more strains of egg type chickens from overseas and reciprocal mating before embarking on selection.

Franchised hatchery industry is involved in the importation of parent stock into the country as day old chicks. The parent stocks are used for the production of commercial day old chicks of the egg and broiler strains. Unfortunately, importation of day old chicks of either commercial or parent stock constitutes a drain on the scarce foreign exchange. Coupled with the depreciating value of naira the price of imported day old chick has become prohibitive.

Oluyemi (1979) has exhaustively discussed the potentialities of indigenous fowls. Akinokun (1976) reviewed the performance of local chickens vis-a-vis imported exotic breeds and crosses between them. He reported annual egg production of 91 eggs to 12 months of lay after one generation of selection increasing to 114 eggs after two generations.

Generally their average performance was very much below the average performance of the imported breeds and the crosses between the imported and the local breeds. Hence, Buvanendran (1979) observed that the production of the local indigenous poultry may be so low that genetic improvement by selection will take many generations before the gap between exotic and indigenous local stock is halved, even though the local poultry may possess some valuable characteristics

such as resistance to diseases as in Egyptian Fayoumi.

Most world-known exotic chickens are available in Nigeria. Their sources of importation include Europe, America, Israel. Nigeria could minimize importation in the future if she begins to practice selective breeding among local and exotic breeds and strains of chickens. On this note a poultry breeding policy was defined for Nigeria in which the long term objective is the establishment of foundation stock for the attainment of self sufficiency (Buvanendran, 1979). Abplanalp and Menzi (1961) have indicated that there is genctype environment interaction between breeds of chickens and their environment. Most breeds of chickens are imported as commercial day old parents or in very few instances as grand parents. Thus, a poultry breeding project for the development of layer foundation stock was established at NAPRI Shika in 1985. The present work will examine the genetic and phenotypic parameters of egg production traits and short term response to selection in the selected lines.

The specific objectives are:

1. To estimate response to selection after five generations
2. To estimate the genetic and phenotypic parameters for egg production traits

CHAPTER 2
LITERATURE REVIEW

2.0 THE DOMESTIC CHICKENS: AN OVERVIEW.

2.1 Origin of Domestic Chickens

Domestic chickens may have originated from four different groups of wild species namely; Gallus gallus, the red jungle fowl of South East Asia; Gallus Laffayettei the Sri Lanka jungle fowl, Gallus sonnerati, the great jungle fowl found in South West Indies and Gallus varius the Javan jungle fowl with green plumage. Two theories have been proposed, namely, the monophylectic and the polyphylectic, to explain the origin of the domestic fowl Gallus domesticus. Oluyemi and Roberts (1979) support the theory that the sole ancestor of the domestic fowl is known as Gallus gallus as proposed by the monophylectic theory adherents. Monophylectic theory was supported by the fact that the domestic fowl most resembles the red jungle fowl and readily breeds with it to produce fertile hybrids. Hence the adherent of this theory believes that Gallus gallus was the sole ancestor of the domestic fowl.

The second theory and that is the polyphylectic believes that all of the wild species interbred with Gallus gallus and domestic stock as known today owe some of its inheritance to all of these species. Oluyemi and Roberts (1979) support this theory.

2.2 Distribution

Man domesticated the wild species of domestic fowl. This may be supported by the fact that the domestic fowl is capable of reverting to the feral state. Mutation

has also been involved in domestication. Such mutations may have been responsible for reduced capacity of the fowl for flight, aggressiveness and hardiness. They might also be responsible for enhanced economic values of the birds. All of the wild species are confined to the Orient specifically South Asia. Oluyemi and Roberts (1979) suggested that the worldwide distribution of the fowl probably followed domestication and probably began when man carried it along with him on his migrations. They opined that the poultry keeping spread rapidly during the first millenium BC i.e. from India and migrated to Persia, Mesopotamia, Asia Minor and appear in the West in about 488 BC.

In addition to migration and mutation, breed differentiation in poultry might have resulted from random drift and selection, which may be natural, in that environmental condition may favour the survival of some genotypes but not the others; or from artificial selection applied to improve some traits of poultry. Today, two very different types of G. domesticus are exploited, one for egg production and one for meat production. In the past, the light breed was used for egg production while the heavy breeds were used for meat production. The use of pure breeds for commercial table bird or egg production has become old fashioned. It has now been replaced by the use of strains and hybrids. Dual-purpose chickens are widely distributed in developing countries, For example in Nigeria, the cocks are kept for meat production and hens for eggs and meat. Both are considerably older when slaughtered than broilers and therefore have better flavor. Older birds are more suitable than broilers for boiling which is a common form of meat preparation in the developing countries.

Example of Gallus domesticus are New Hampshire, Plymouth Rock, Wyandotte, Jersey Giant (all American); Orpington, Australorp, Light Sussex (Dutch); Fayoumi (Egyptian); Campine (French).

2.3 History of breeding

Individual farmers, who set their own standards for their stock and selected birds that exhibited what were seen to be desirable characteristics, historically, developed breeding policies in the Western Hemisphere. Birds that show undesirable characteristics were prevented from contributing to future generation. The selected birds were mated together in the hope that they would also show these desired characteristics. The success that they achieved depended to a large extent on characters for which selection was carried out. This type of selection often involved selection for characters controlled by one gene or a few genes e.g. comb shape and plumage colour.

The use of trap nesting in the early part of the 20th century has definitely enhanced breeding in poultry industry. It should be noted that the breeding technique applicable in any particular situation is determined largely by heritability of the trait, which is being improved. The process of genetic improvement based on choosing as parent the best within a population (breed, strain, herd etc) is sometimes regarded as too slow for use in developing countries compared to rapid result that could be obtained by crossing local chicken with the exotic breeds.

2.4 Basis of selection

Attributes of animals have been changed by nature and by man through selection. Since in the process of selection some animals are chosen in preference to others, it follows that frequency of particular gene change between parent and offspring and in this way change performance. Response to selection is directly proportional to the heritability estimate, h^2 while $h^2 = \frac{V_A}{V_P}$. V_A, which is the variance component due to additive genetic effects and is the chief component of resemblance between relatives. When additive variance V_A is high, h^2 will be high and when V_A is low, h^2 will be low. In consequence h^2 will give more response where h^2 is high since $R = h^2 * SD$ where R is response to selection and SD, selection differential which is the superiority of the selected parent over the mean of their group. The smaller the proportion selected the higher the selection differential.

Accuracy of information obtained on individual is very important. If the trait is of low heritability, it may be essential to obtain many records from relatives. Generation interval is very important in the determination of the rate of genetic gain over generations. Dempster and Lerner (1947) proposed the use of earlier partial egg records as a selection criterion for improving egg production. This proposal was aimed at reducing the generation interval, which will increase the genetic gain per unit time. This idea was theoretically confirmed by Lerner and Cruden (1948) and Morris (1964) based on parameter estimates in different populations. Erasmus (1962) and VanVleck and Doolittle (1964) provided additional support for this theory from what appear to be phenotypic correlation effects and genetic parameter

estimates respectively in a Cornell control population. Oliver et al. (1957) provided further support.

Dempster and Lerner's hypothesis is not without opponents. Kraszewska-Domanska (1959, 1962a,b, 1963) consistently opposed the use of early partial records on the basis of small positive phenotypic correlations between early part annual records and a high frequency of negative phenotypic correlations between the initial part records and production in the residual period. However, the result of analysis of four breeds over years (Kraszewska-Domamanska, 1964) showed that selection on only part records should be 26% more effective per year in improving the annual records than selection on the annual record. Bohren (1970) concluded that selection on early partial records either in number of eggs or percent production should be more efficient in increasing annual egg production.

Lerner and Dempster (1956) also showed that part year selection was more efficient in improving the annual record. Morris (1963, 1964) and Gowe and Strain (1963) raised serious doubt as to the validity of this hypothesis. They concluded that while gains were made when selection was based on part record, no appreciable improvement was made in residual egg production. It followed therefore that egg production declined in the residual period in proportion to the gains made in early partial record. For this to happen the genetic regression of residual period number of egg on the partial record will have to be -1.0 and genetic correlation between the two traits will be negative.

Bohren *et al.*, (1966, 1970) have indeed shown that theoretically, genetic

correlation between partial and residual egg record could change from positive to negative in the course of selection. However there is no evidence that such change has taken place in practice. Hale and Clayton (1965) reported an average of 0.45 as genetic correlation between partial and residual egg number from Light Sussex and brown Leghorn populations. Abplanalp (1957) reported 0.55 from a commercial White Leghorn population. Andrews (1966) reported positive genetic correlation between part and residual period percentages of production. Morris (1964) and Bohren *et al.*, (1970) reported genetic correlation of 0.92 and 0.58, respectively, while Bohren *et al.*, (1970) reported 0.38 between numbers of eggs in the two periods.

Caceres (1967) reported that there was consistent gain in part period residual and annual number of eggs in a population where selection was strictly for number of eggs in part period. Both age at sexual maturity and egg weight declined. The estimate of the realized genetic correlation between partial and residual records over eighteen generations was 0.57 while that between partial and annual egg records was 0.85. Bohren (1970) therefore concluded that the selection based on partial egg record to improve the annual egg record will be valid for some populations when selection is only on number on eggs in the part period. But response may be erratic when selection for other traits is included. Under this situation the responses will be dependant upon the genetic correlations of the traits with egg production and the amount of selection applied to the secondary traits. Bohren (1970) again concluded that selection on part record percent production is more efficient in some populations than selection on annual percent production.

Low genetic correlation may result from data not corrected for hatch effect as observed in the report of Oliver (1957) who observed 0.22 genetic correlation between short term egg numbers and percent production. When estimate was however made within hatches Bohren *et al.*, (1970) observed a correlation of 0.79 while Morris (1964) obtained a value of 0.74 from data corrected for hatch effect.

2.5 *Principle for the construction of the selection indexes.*

For traits of low heritability, selection of complete families of full or half sibs without regard to individual performance is more efficient than selection on individual phenotypes. However for higher values of heritability the situation may be reversed but in all cases maximum efficiency can be obtained by selecting on the basis of combination of family average and individual record.

Lush (1947) described the relative merits of individual selection and family selection in breeding for traits of low heritability while Lerner (1950) did the same with particular reference to poultry breeding. Based on these works, for traits of low heritability, selection of complete families of full or half sibs without regard to individual is more efficient than selection on the basis of individual phenotypes.

Maximum efficiency can be obtained by selecting on the basis of a combination of family average and individual record. This is because there is no fine distinction between when to apply individual or family selection. This is known as selection index. Such indexes have been constructed and used by Hazel (1943)

and Osborne (1957a,b). The prediction of a female breeding value is obtained from her own performance (phenotype) and the means of her full sisters and half sisters. However, in egg production studies, virtually all the traits studied are manifested in females only. Therefore, the prediction of the male breeding values is obtained from the means of his full sisters and half sister (Liljedahl *et al.*, 1979).

2.6 Selection methods

The success of any breeding work and indeed its efficiency is dependent upon three factors that include the intensity of selection, the accuracy of selection and the generation interval (Dickerson and Hazel, 1944). The first factor, intensity of selection is that proportion of the population that is allowed to be parents of the following generation. It may also be measured as the average superiority of the selected individuals above the average of the whole group. This is referred to as selection differential.

The second factor, and that is the accuracy of selection, depends on some factors. It should be noted that characters being selected for can only be measured on phenotypic term since there is no possibility of measuring such a character based on the genotype. Phenotypic value of any trait is made up of portion due to genetic constitution for the trait and the environmental factor. Only part of the total variation between animals in a given character is directly due to genetic differences between animals. Therefore the phenotypic identification of genetic superiority of an individual with respect to a given character is subject to errors proportional in magnitude to the degree to which non-genetic sources of variation affect it. In other words the accuracy of selection of genotypes by

phenotypic measurement of individuals is proportional to the degree of heritability of a character. Since only the fraction of variation determined by heritability of a character will contribute to improvement then the rate of change in genetic composition of a population will be dependent on that fraction as well as on the intensity of selection. Better estimate of the genotype of an animal can be obtained if information about the phenotype of animals related to it is available. Such information is obtainable from full-sibs and half-sibs of a given animal or from its offspring. This will enable the breeder increase the accuracy of selection.

The last factor, which affects the efficiency of selection, is the interval between generations. When the average age of parents of a given generation is lower, less information about the animal is available to the breeder consequent upon which the accuracy of selection decreases. For larger animals, Dickerson and Hazel (1944) showed that the reduction in the age of parent would more than compensate for the advantage of the increase in accuracy of selection by progeny testing, when the progeny tested information is not available early in the life of an animal even when reproductive rates are relatively high and individual heritability is low. Dempster and Lerner (1947) showed that greater efficiency is obtained by more widespread use of younger birds. They suggested that the use of pullets not only leads to more rapid improvement but also results in a considerable saving in the cost of breeding operation. Lerner and Cruden (1948) suggested that selection might be done based on a part record thereby reducing considerably the interval between generations. Their estimate of genetic correlation between part period

production and total production on a survivor basis was 0.74.

2.7 Primary trait of economic importance

Since the principal objective of a poultry breeder is to produce a strain of poultry that will lay the maximum number of eggs within one year from sexual maturity, the primary trait normally selected for is egg number. In order to reduce the generation interval from two years to one year, egg production to certain fixed age has been taken as the norm in poultry breeding and selection work (Bohren 1970). Secondary traits include age at sexual maturity, egg weight and body weight. Egg production is the major index of performance of the layer's productivity.

A chicken will lay for close to 365 days, which can be divided into three phases according to Oluyemi and Roberts (1979). Phase one include the first 3 month of laying. It starts from about point of lay to about the peak at about 2 - 3 months after point of lay. During the period egg size and body weight increase. This first phase ends at about the twenty-second week in some strains. This is followed by phase II that is characterized by a gradual fall in production but not in egg size or body size. This phase lasts till about forty-second week from point of lay. Phase III is made up of the remaining pullet year and terminate in the moulting.

In order to reduce the generation interval by half, when selecting for egg production, record of egg production to about 40 to 42 weeks of birds are normally used. Correlations of egg production to 40 to 42 weeks, referred to, as partial egg production with residual egg production is high. Correlation of partial egg

reviewed correlation of partial egg production, with full year production. Oluyemi and Roberts (1979) reported that hens produce eggs in about 26.5 hours under normal photoperiod of about 12 hours as found in Nigeria.

2.8 Response to Selection

2.8.1 Direct response.

Using 4 strains of White Leghorn, Srivastava *et al.,* (1989) reported genetic response per generation after 4 generations of selection ranging from 2.48 to 3.23 eggs per generation or per year. They observed close agreement between predicted and realised response for strain while in the remaining 3 st... realised response was approximately 1.5 times that of the predicted response. Such disparity in responses could be caused, among other factors, by genetic drift, error of measurement, genotype-environment interactions, time trend and natural selection (Hill, 1972a,b).

In the work reported by Srivastava (1989), the only possible reason for variable responses among the four strains could either be genotype-environment interaction or due to correlated responses. Kinney and Shoffner (1967) suggested that the nature of genetic variance present in each strain may also contribute to estimated response. Poggenpoel and Erasmus (1978), Ayyagari *et al.* (1980) and Barua (1983) reported variable results between realized and predicted response. Gowe *et al.* (1959) reported significant regression of 3.71 eggs per generation without correction for environmental effects. After correction for environmental effects using random bred control line regression reduced to 1.26 eggs per generation which was not significant Poggenpoel and Erasmus (1978) reported

control corrected regression coefficient of 3.04 eggs. Morris (1963), Mohapatra and Srivastava (1971) reported gain of 3.0, 3.1 and 2.01 eggs per generation respectively. Johari *et al.* (1989) reported positive and significant response to selection for part period egg production ranging from 1.44 to 2.21. Gowe and Fairful (1986), Poggenpoel (1986) and Lie (1988) supported these results in their reports on White Leghorn. Brah *et al.* (1986) reported gains ranging from 2.60 to 3.40 eggs per generation. Liljedahl and Weyde (1980) reported gain ranging from 4.4 to 6.2 per generation over 4 years of selection. Nordskorg *et al.* (1974) found no appreciable response in their White Leghorn line selected for part record rate of lay until 8th of the altogether 11 generations of selection for which the realized heritability was estimated to be 0.07.

Kolstad (1980) reported highly significant response for egg number. This he attributed to two factors, which were reduced age at sexual maturity and higher intensity of lay.

2.8.2 *Correlated Responses*

Age at sexual maturity. Liljedahl and Weyde (1980) reported that age at sexual maturity is one of the two components that contribute to selection response in population of chickens selected for egg number to 280 days. They reported that the contribution at sexual maturity to response to selection range from 50 to 80% over four generations of selection. They also demonstrated a linear decline in ASM by about 5 days per generation during the first three generations and increased in the fourth generation. Kolstad (1980) showed that age at sexual maturity as correlation response to high egg production was significantly lowered by 4.2 days

per year. Age at sexual maturity and rate of lay he concluded contributed equally to the gain achieved in egg number.

Brah *et al.* (1987) noted that correlated response in ASM ranged from -2.29 to -3.61days in four populations of chickens consisting of two purelines and their reciprocal crosses. They also noted that the bulk of improvement in egg number was due to reduction in age at sexual maturity, which declined significantly in the purelines and crosses. Their results were in agreement in with Saadeh *et al.*, (1968), Kolstad (1980), Liljedahl and Weyde (1980) and Ayyagari *et al.* (1982). Srivastava *et al.* (1989) reported correlated changes per generation at sexual maturity ranging from -2.9 to -3.7 days per year. They concluded that reduction in age at first egg in different strains might have contributed positively to improved egg number because of the increase in number of production days.

2.8.3 Egg weight

Liljedahl and Weyde (1980) noted a rapid decline in egg weight in population selected for egg number. They reported the cumulative response to selection to be -3.2 grams. Kolstad (1980) reported a decrease in egg weight of 0.29g per generation as a result of selection on egg number. His result also indicated that total egg mass estimated by egg number multiplied by egg weight, showed considerable improvement per year inspite of drop in egg weight. Johari *et al.* (1989) reported decline in egg weight ranging from -0.172 to -0.44g per year in four strains of White Leghorn selected for part period egg number over 11 generations. Brah *et al.*, (1986) reported a decline in egg weight of -0.12 g per year for one of the two purelines which had under gone selection. However, for

both strains in his study the change in weight were not significant. Srivastava *et al.*, (1989) in the analyses of populations of four strains of White Leghorn breed over five generations of selection reported correlated response to selection of -0.27 to -0.47g in egg weight per generation.

2.8.4 Body weight

Kolstad (1980) reported gain of 11.8 g per year in body weight at 40 weeks. This increase in body weight over year was not statistically significant. This was because there was a corresponding change in the control population. This also showed that the increased body weight was more as a result of environmental factors than genetic effect.

2.9 GENETIC PARAMETERS

2.9.1 *Egg Number*

In describing egg production in the domestic fowl, the criteria used include number of eggs produced to 280 days also known as part period egg production and egg number to 500 days which may be referred to as full year egg production. These two measures are defined as the number of eggs that a hen lays after placement in the laying house. When these methods are used, zero egg is a valid observation for an individual hen. Of these two methods, the more used criterion in most poultry selection work is the part year egg production, which has the characteristic of reducing the generation interval by half consequent upon

which the rate of genetic gain is increased. Part year egg production is a combination of three component traits: age at first egg, rate of egg production and viability. These three traits are highly correlated with part year egg production.

Another measure of egg production is Hen day rate of lay which is the number of eggs laid divided by number of days a hen was alive in the period. Calculation normally starts from age at first egg.

Heritability of egg production is generally low. This is an indication that variability due to additive gene action is probably small. Low heritability could also be an indication that non-additive gene action such as overdominance, dominance and epistasis may be important. Heritability estimate of egg number determined from dam component of variance is generally higher than that determined from sire component. This may imply that there is a large maternal effect and/or dominance deviations. This view is supported by Brah & Dev (1987), Jerome *et al.*(1956). They all indicated maternal effects for rate of lay. Kinney (1969) reported that average h^2 for short, intermediate and long term did not vary much from one another being 0.22, 0.19 and 0.22, respectively based on sire variance component. Due to maternal effect and dominant deviation the h^2 estimates from dam component of variance were reported to be more than 30% higher than those from sire component of variance. They were 0.32, 0.35 and 0.30, respectively. However, Osborne (1953) attributed these to sex linked effects. These views were however not supported by Roberts *et al.*,(1952) and King and Henderson (1954).

2.9.2 *Egg weight:*

Egg weight is a very important correlated trait in any population of chickens selected for egg production. Eggs, which are too small, will not receive the premium price. On the other hand, eggs, which are too large, will require excess feed to produce them for which the poultry man will not be compensated when he sells his eggs. In addition such large eggs are more apt to be broken on the way to market and hatching. Egg weight and size are usually influenced by the productivity level as well as the age of the pullet at point of lay. Egg weight seems to have fairly high degree of heritability. This is an indication that heredity rather than environmental factors affect this trait. However, selection for high rate of lay results in a decrease in egg weight. From the point of lay when egg weight is 38-43g, there is a linear increase of 1g per week up to 6-7 months when the size levels off. On the average, eggs weight of chicken range between 50 and 60g.

Although the heritability estimates of egg weight have been shown to be high, wide variations have been reported in literature. This was so for both light and heavy breeds. The values of heritability estimates for pullets and matured weight were not different for both light and heavy breeds. This indicates that pullet and matured egg weights are inherited in the same fashion. In the report of Kinney (1969) maternal and or dominant effect have been shown to affect pullet egg weight. This was due to a 15% difference between variance component estimates from maternal half sibs and paternal half sibs in favour of maternal half-sib estimate.

2.9.3 *Age at sexual maturity*

The age at sexual maturity is an important factor in determining the number of eggs laid to a fixed age. It is defined as the age at which a pullet laid her first egg. Hens that laid their first egg at an early age are more preferred than those that lay theirs at a later age. The heritability estimates for this trait are moderate being approximately 0.38 in both heavy and light breeds. This shows that environmental factors have a very important role to play in the phenotypic expression of this trait. Such factors include lighting and feeding programs. In addition to these factors, bird's physiological thresholds essential to start egg production are dependent on age, body weight and carcass composition. In support of these views Brah and Dev (1987) indicated positive skewness in two strains of White Leghorn chickens over six generations. Since age at sexual maturity has moderately high heritability estimates, it was showed that it could easily be decreased by direct selection and also by selection for increased egg number (Srivastava *et al.*, 1989, Kolstad 1980, and Sorensen *et al.*, 1980). It has been observed that age at sexual maturity may be affected by sex linked genes. This was supported by work done on a flock of Rhode Island Red birds and demonstrated by higher heritability estimates from sire variance component (0.30 ±0.12) than that from dam component (0.18±0.11). Jerome *et al.*(1956) and Saadeh et al. (1968) had earlier reported similar situations for New Hampshires and Rhode Island Red chickens, respectively.

2.9.4 *Body Weight*

Body weight at particular age is an important trait in breeding for layer type chickens. Ayorinde *et al.*(1988) reported that body weight ranging from 1728 - 1814g is required for satisfactory performance in layers generally. Small-bodied

layers are known to be efficient utilizers of feedstuffs than large bodied layers. Body weight is highly heritable. These estimates are fairly high when measured at any given age. The size of heritability estimate is independent on whether they are of small body or large body. Body weights have been shown to be influenced by maternal effect or dominance or both effects up to maturity as indicated by consistently higher heritability estimates from dam variance components as opposed to those from sire components. Sex linked effect has also been reported by Jerome *et al.* (1956). Heritability estimates of body weight vary from one study to another (Kinney 1969). Kolstad (1980) reported heritability estimate of 0.68.

In developed countries, the tendency has been to select for strains that have small body weight since this ensure a lower maintenance and food requirement and therefore more efficient production of eggs. This approach can be justified because in the developed countries, market for old layer carcasses is very small. This is different from what obtain in many developing countries as old or spent layers are preferred to broilers. The spent layer is therefore more valuable than broilers. In addition to the fact that egg weight is positively correlated with body weight, there is an indication that somewhat heavier laying birds are more desirable in developing countries.

2.10 CORRELATIONS

Correlations can be phenotypic, genotypic or environmental. Phenotypic correlations among traits can be defined as the gross correlation that includes both

correlations were respectively -0.004 and -0.09. These estimates are similar to those reported by Craig *et al.*, (1969) but at variance with estimates of Poggenpoel and Erasmus (1978) and Srivastava (1985). They reported that egg production to 280 days was to a large extent independent of 40-week body weight. Atkare and Khan (1988) reported moderate to high genetic correlation between body weight at 40 weeks and egg weight at 40 weeks which was in agreement with Friars *et al.*, (1962).

VanVleck, King and Doolittle (1963) demonstrated that when there is large maternal effect the genetic correlations between two traits might carry opposite signs. For example, they reported that genetic correlation between egg production and 32 week egg weight were -0.28 and 0.01 from sire and dam component respectively. The opposite signs exhibited by the sire and dam components estimates for the correlation between egg production and 32 week egg weight are an indication that maternal effect need to be reckoned with when designing programme for such population. The report of VanVleck, King and Doolittle (1963) also show that phenotypic correlations were generally of lesser magnitude than corresponding genetic correlation regardless of signs. Therefore, if only phenotypic correlation is considered in a selection programme, one could be tempted into a false security and thereby give less weight to correlated responses. They also reported correlation 0.32 and 0.18 between 32-week body weight and egg weight at 32 week as well as between sexual maturity and egg weight respectively. These estimates agreed very well with earlier estimates of King

(1961). Hogset and Nordskorg (1958) reported phenotypic correlations of +0.37, -0.06 and -0.04 between egg weight and body weight, egg weight and egg production and body weight and egg production, respectively.

Negative genetic correlation between body weight and egg production could arise through the positive association of body weight with egg size. Liljedahl *et al.,* (1979) reported that egg number and age at sexual maturity were strongly negatively correlated. They reported -0.18 and 0.05 for genetic and phenotypic correlations respectively between egg number and egg weight. Higher genetic correlations are often obtained for populations that have been selected over a number of generations.

The present study involves estimating short-term response to selection and multi-locational performance of commercial layer resulting from the crossing of the male and female line. Since this is a long-term project, various aspects of it have been analysed and the results reported (Omeje, 1987; Oyedepo, 1989; Oni et al., 1991; Abubakar et al., 1992; Ajeigbe, 1992; Oni et al., 1992 Mshelia, 1993; Abubakar et al., 1994; Abubakar et al.; 1995).

CHAPTER 3

MATERIALS AND METHODS

3.1 The location of the project

The poultry Breeding Project is located at the National Animal Production Research Institute, Shika, Zaria, Nigeria. The station is geographically located between latitude 11 and 12° N and longitude 7 and 8° E at altitude 640 m above sea level. This area is vegetationally in the Northern Guinea Savanna Zone. The average annual precipitation is 1100mm. Rainfall normally start in late April or early May, peaked between June and September and lasts to October. The Harmattan, which lasts from Mid October to January, is immediately followed by dry hot weather from February to May. Temperature during the harmattan season ranges from 14°C to 30°C and 21 to 36°C during the hot season. Relative humidity varies from approximately 21% during the harmattan to 37% during the hot season. The average temperature and humidity during the wet season are 24.8°C and 77% respectively.

3.2 Synthesis of Common base population

a) *Description of the original stock*

Omeje (1987) gave a complete description of the foundation stock and the breeding activities prior to the commencement of the selection activities. A total of 1411 day-old grandparent chicks were imported between February and April 1985. They belonged to two strains of egg type chickens. Both sire line and dam-line were present within each strain. The sire-line was golden or brown in colour while

dam-line has white or silvery plumage.

For the formation of F_1 generation the parental strains were crossed according to a polyallelic system. For this purpose, mating was arranged among the surviving 994 and 200 hens of dam-line and sire-line respectively and their matching 129 and 37 cocks to produce the F_1 generation chicks of 4 different genotypes each in both sire-line and dam-line (Table 1).

Table 1 Mating arrangement between cocks and hens of the two strains of grandparent stock[1]

Sire line			Dam line		
	Hens			Hens	
Cocks	A1 (71)	B_1 (129)	Cocks	A2(490)	B2(504)
A1 (22)	A1. A1 (11).(35)	A1.B1 (11). (66)	A2(76)	A2 . A2 (38) . (250)	A2 . B2 (38) . (260)
B1(15)	B1.A1 (7) . (36)	B1. B1 (8) . (63)	B2(53)	B2 . A2 (26) . (240)	B2 . B2 (27) . (244)

[1] Omeje (1987)

A total of 2555 hens and 256 cocks from 8 genotypes produced from above mating arrangement which are referred to as F_1 were mated at about 4th November 1986 using a 4 X 4 diallel system (Table 2).

Table 2: A diallel cross arrangement of F_1 cocks and hens within sire and dam lines[2]

Sire line					Dam line				
	Hen					Hen			
Cock	A1A1 (286)	B1A1 (317)	A1B1 (334)	B1B1 (263)	Cock	A2A2 (369)	B2A2 (375)	A2B2 (303)	B2B2 (318)
A1A1 (31)	1 8:80[a]	2 8:79	3 8:79	4 7:70	A2A2 (35)	1 9:94	2 10:100	3 8:77	4 8:84
B1A1 (30)	5 7:66	6 8:82	7 8:78	8 7:65	B2A2 (34)	5 9:92	6 9:93	7 8:78	8 8:77
A1B1 (30)	9 7:72	10 8:82	11 8:81	12 7:67	A2B2 (34)	9 9:90	10 9:92	11 8:76	12 8:78
B1B1 (29)	13 7:68	14 8:81	15 8:79	16 6:61	B2B2 (33)	13 9:93	14 9:90	15 7:72	16 8:79

[2]Omeje (1987)
[a]The male: female ratios for each mating are indicated within each square

Crossing was restricted to within lines since the aim was to develop strains of each parent pair separately. There were, therefore, two sets of diallel crosses, one on the male line and the other on the female line. A general mating ratio in both sire-line and dam-line of 1:10 was used.

The mating for the formation of F_2 generation were set up using a 4 X 4 diallelic crossing technique. After the formation of F_2 generation, the population was randomly mated for one more generation to produce the F_3. The selection work began with the F_3 generation. In the F_3 generation, the base population was divided into four selection lines and two control lines as follows.

Population 1 Line to be selected for Egg number male line.

Population 2 Line to be selected for Egg number female line.

Population 3 Line to be selected for Egg number and egg weight combined into an index (male line).

Population 4 Line to be selected for Egg number and egg weight combined into an index (female line).

Population 5 Control line reproduced by Random mating (male line).

Population 6 Control line reproduced by Random mating (Female line).

b) *Selection and mating procedure*

i. Population I - IV Selection lines Generation 0.

At 18 weeks, 500 females were randomly selected from each line and housed in individual cages. Records of production for each bird were kept from the day of first egg to 120 days of production. One hundred and fifty birds were later selected out of the 500 birds based on the number of eggs produced to 120 days after laying the first egg (Populations I and II) or index for egg number and egg weight (Populations III and IV).

Similarly 17 cocks were selected from each line of the F_3 chicks based on body conformation. Selected male and females were mated by trapnesting using a mating ratio of 1:9. Egg collection started 2 weeks after introduction of the cocks. Each egg was labeled with sire identification number, dam identification number and population number.

Generation 1

One thousand two hundred females and 200 cocks were pedigree hatched for each line. Chicks were wing-banded at day old, brooded and reared to 18 weeks. Five hundred females were transferred into individual laying cages and record of production from point of lay to 120 days in lay was kept. At the end of the production period, 150 females and 17 cocks were selected based on number of egg produced to 120 days from point of lay for populations I and II and egg number and egg weight combined into an index for populations III and IV. Breeding and selection in subsequent generations were similar to generation 1.

ii. Populations V and VI Control lines

Generation 0

At 18 weeks, 150 hens from the base population were to be tagged. The tagged pullets were moved to individual cages and record of egg production for each bird was kept from age at sexual maturity to 120 days in production. Seventeen cocks were randomly selected from the base population. The chosen males and females were mated by trapnesting.

Generation I

Six hundred females and 100 males were to be pedigree hatched for each line. Chicks were wing-banded at day old. At 18 weeks 400 females were moved in to individual laying cages and record of egg production kept for each chicken from age at first egg to 120 days in lay. At the end of the monitoring period, 120 hens and 13 cocks were randomly selected, leg banded and mated together in mating pens that contain trapnest. Breeding of subsequent generation was as in generation I.

At the beginning of the selection experiment, selection was based on egg production from point of lay to 120 days in lay for each hen. This procedure was very clumsy as analysis of data could not be done until all hens have laid for 120 days. This procedure was later changed and selection has since been based on egg production to a fixed age of 280 days for each of the hens housed in individual cage.

Another modification to the initial plan was the fact that 1000 and 250 hens were monitored for individual production for selection and control lines, respectively. At the end of the monitoring period, 252 hens were selected out of the survivals among each of the selection lines. The top 28 cocks were also selected.

3.3 Mating procedure

Within each line, 9 hens were placed in each mating pen. Each mating pen was equipped with trapnest, conical feeder and drinkers. One cock of the 28 selected cocks was allocated to each pen. The cock was located such that half-sib or full sib mating is totally avoided.

3.4 Data.

The data consisted of over 4000 records of hens from about 180 cocks mated to about 1,500 dams. These records were collected over five generations of selection.

Basis of selection

On an annual basis, selection indexes were constructed for the purpose of estimating the breeding value of each breeding animal. This selection index constructed was based on the conventional type developed by Hazel (1943); Osborne, (1957a,b); Henderson (1963). The female's breeding value was predicted from her own phenotype (Performance) and the average (means) of full sisters and half sisters. However, since virtually all of the traits studied were manifested in females only the male's breeding value was predicted from means of his full sisters and half sisters. In notational form, the indexes can be written thus.

$I_{\varphi} = (P - X) + b_1 (D - X) + b_2 (S - X)$

$I_{\sigma} = b_3(D' - X) + b_4 (S' - X)$

Where X = population mean for the trait

P = a female breeding candidate's phenotypic value for the trait.

D and D' = average phenotypic values for the trait of full sisters of a female and male breeding candidate, respectively.

S and S' = average phenotypic values for the trait of half sisters of a female and male breeding candidate, respectively.

b_1 , b_2 , b_3 and b_4 = regression coefficients of the trait on the index for females and males

$$b_1 = \frac{2n(1-h^2)}{4+(n-2)h^2} \quad \text{and} \quad b_2 = \frac{4nd(1-h^2)(2-h^2)}{(4+(n-2)h^2)(4+n(d+1)-2)h^2}$$

$$b_3 = \frac{nh^2}{(4+(n-2)h^2} \quad \text{and} \quad b_4 = \frac{2ndh^2(2-h^2)}{(4+(n-2)h^2)(4+[n(d+1)-2]h^2)}$$

Where d is the number of dams

n is the number of offspring per dam

h^2 is the heritability estimate

Birds within generation were hatched over more than 3 hatches. Data were usually corrected for hatch effect using Least Squares procedures described by Harvey (1966) when hatch to which a bird belongs has a significant effect on the trait being evaluated. The hatch-corrected data is then used for subsequent genetic analysis. Heritability estimate so obtained is then used to obtain the weights b_1, b_2, b_3 and b_4 used in the construction of the selection indices.

This procedure gives unbiased predictions of the selection response, as the index values are unbiased estimates of the animal's additive -genetic values.

3.5 Numbers of Experimental animals.

The aim was to monitor 1000 and 250 hens individually up to 280 days each line of selection and controls, respectively. The actual numbers of hen monitored vary from this idealized number from year to year depending on factors such as fertility, mortality, feed availability and economic situation of the institute.

3.6 Hatching Procedure

New generations of chicks were hatched at the institute's hatchery using the Western incubator of 19,000-egg capacity over 3 to 8 hatches hatched at one-week interval. This was made possible by collection of fertile eggs marked with sire and dam identification over seven-day period and on the 8th day the egg were set in the

incubator. Fertile eggs are stored in a Dublino 3 TN Tropic cabinet egg cooler with refrigerating power of - 10°C.

After hatching, the chicks were identified using wing band and vaccinated against New Castle disease using New Castle Disease Vaccine administer intra ocularly. After the procedure has been completed, the chicks were moved from the hatchery to the brooding and rearing house about 2 km from NAPRI hatchery.

3.7 Environment of selection lines and control

Birds were brooded and reared on the floor in the restricted Grandparent section of NAPRI Poultry Farms. The brooding equipment included 0.61 x 2.44m (2ft x 8ft) ply wood sheets that serve as heat breaks for kerosene stoves, electric bulbs (100 watts), and small plastic flat feed containers and metallic drinkers were used. Chicks were brooded from day old to 6 weeks and were evacuated as soon as possible to the rearing house. Sexing was done at about 8-12 weeks. At 18 weeks, birds were moved to cage house where the females were housed in single hen cage (900 cm^2/bird). The cocks were housed on the deep litter until the end of the monitoring period.

3.7.1 Housing

Two types of housing systems were used for this project. Birds were raised on the deep litter from day old to about point of lay when they were transferred to individual laying cages. Deep litter houses included grower and mating houses. The brooder house was made of sidewalls raised almost to the roof to enable the pens

retain heat during the cold and wet weather. The house was partitioned into brooding pens each of 2.3m x 3.1m (7ft x 10ft) dimension and surrounded by wire netting. There were 8 houses in all, and each house measured 65.5m x 7.6m (215ft by 25ft). Each house was made up of two wings each measuring 30.48m (100ft) in length. The two wings were separated by holding room measuring 4.6m x 7.6m (15ft x 25ft). The houses except the cage house were partitioned into smaller pens. The house earmarked for mating was partitioned into 40 pens per wing. Each pen measured 1.502 x 3.05m (5ft x 10ft). The other buildings were partitioned into bigger pens meant for rearing during the growing stage. All buildings had low side walls that were finished to the roof with wire netting. The end of each building had complete walls to the roof (Omeje, 1987).

3.7.2 Nutrition

Chick ration containing 20% CP and 2722kcalME/Kg was given to the chicks up to 8 weeks (Table 3). The ration was changed to grower ration containing 16% CP and 2737kcal ME/kg from 8 weeks to point of lay.

Table 3: Experimental chick, grower, layer and breeder rations

	Chick mash	Grower Mash	Layer Mash	Breeder Mash
Crude Protein	20.01	15.56	16.60	16.60
Energy	2722	2737.0	2594.00	2594.00
Maize (%)	45.00	34.45	43.45	43.45
Maize offal (%)	10.00	10.00	10.00	10.00
Groundnut Cake (%)	13.05	10.00	13.50	13.50
Soya bean cake (%)	20.90	10.50	13.00	13.00
Wheat offal (%)	6.00	15.00	09.00	9.00
Rice offal (%)	0.00	15.00	0.00	0.00
Bone Meal (%)	3.00	3.00	3.00	3.00
Limestone (%)	1.50	1.50	7.50	7.50
Salt (%)	0.30	0.30	0.30	0.30
Premix (%)	0.25	0.25	0.25	0.25
Total	100	100	100	100

3.7.3 Recording of Data

Trained recorders collected data. Eggs collected were recorded in daily egg record book, which was summarized at the end of every month. Egg weights were taken using electronic balance located in the central laboratory at weeks 35, 36, 37 and 38. Hens were also weighed at 40 weeks.

3.7.4 Traits Used

The traits considered in this project included number of eggs, egg weight, age at sexual maturity, body weight at 40 weeks.

Egg number: Eggs laid were recorded and collected on a daily basis up to 280 days.

Egg weight (gm): This was obtained by taking the average weight of eggs at 35, 36, 37 and 38 weeks.

Where μ = Population mean

h_i = Effect of i^{th} Hatch

e_{ij} =random error (Error terms were assumed to be randomly and normally distributed with expectation equals to zero.

Where hatch is found to have a significant effect, the data was transformed by adding or subtracting a certain constant as per Harvey (1966) method.

3.8.2 Estimation of genetic parameter

Genetic parameter was estimated using the full model whereby the variance component was partitioned into those due to sire, dam or environment. The model fitted was of the nested or hierarchical design (Henderson, 1953).

In this design, each sire was mated to several dams and each mating produced several progeny.

Statistical model

$$Y_{ijk} = \mu + a_i + b_{ij} + e_{ijk}$$

Where Y_{ijk} is the record of the k^{th} progeny of j^{th} dam mated to the i^{th} sire.

μ is the common mean.

a_i is the effect of the i^{th} sire

b_{ij} is the effect of the j^{th} dam mated to the i^{th} sire

e_{ijk} is the uncontrolled environmental and genetic deviations attributable to the individuals (All error terms were random, normal and independent with expectation equal to zero).

Analysis of variance

Source of Variation	df	Sum of Squares	Means Squares	Expected Sum of Squares
Between Sires	S-1	SS_S	MS_S	$\sigma_W^2 + K_2\sigma_D^2 + K_3\sigma_s^2$
Between dams within sires	D-S	SS_D	MS_D	$\sigma_W^2 + K_2\sigma_D^2$
Progeny within sires	N..-D	SS_W	MS_W	σ_W^2

S = Number of sires

D = Number of dams

n_i = Number of individuals within i^{th} sire

n. = Total number of individuals

K_2 = Number of offspring per dam

K_3 = Number of offspring per sire

The variance component σ_s^2 is due to the fact that the sire groups differ. These groups are made up of half sibs, and therefore the variance component is equivalent to the variance between half sibs. The variance component σ_D^2 is derived from differences between dam groups. These groups are made up of full sibs, and therefore the variance component is equivalent to the covariance between full sibs minus the covariance of the sire half-sib groups because the sire effect is removed in the analysis of variance.

The variance component σ_w contains the remainder of genetic variance and the environmental variance. The variance components estimates 1/4 of the additive genetic variance, 1/16 of the additive X additive genetic variance and various amount of sex linkage variance depending upon the sex and species. The σ_W^2 estimates the remainder of the genetic variance plus all environmental variance.

Estimating variance components.

$\sigma_w = MS_W$

$$\sigma_D = \frac{MS_D - MS_W}{K_2}$$

$$\sigma_S = \frac{MS_S - MS_W + k_2 * MS_D}{k_3}$$

$\sigma_T = \sigma_S + \sigma_D + \sigma_W$

heritability,

$$h_S^2 = \frac{4 * \sigma_S^2}{\sigma_T^2}$$

$$h_D^2 = \frac{4 * \sigma_D^2}{\sigma_T^2}$$

$$h^2_{S+D} = \frac{4 * \sigma^2_{S+D}}{\sigma_T^2}$$

Where k_2 = Average number of progeny per dam

and k_3 = Average number of progeny per sire

Alternatively, genetic parameters was also estimated using the reduced model whereby the variance component was partitioned into those due to sire or environment. In this design, the statistical model is

$Y_{ij} = : + a_i + e_{ij}$

Where Y_{ij} is the record of the j^{th} progeny of i^{th} sire.

μ is the common mean.

a_i is the effect of the i^{th} sire

e_{ij} is the uncontrolled environmental and genetic deviations attributable to the

individuals (All error terms were random, normal and independent with expectation equal to zero).

3.8.3 Estimation of correlations

The genetic, environmental and phenotypic correlations between two traits will be obtained by a method similar to those used to estimate heritabilities.

1. *Single parent design, one way layout.*

The models and procedure for analysis were the same as for estimation of heritabilities. Each trait X or Y should be analysed as given for heritability estimate. In addition the analysis of covariance between X and Y should be carried out.

Analysis of covariance

Source of Variation	df	Sum of Cross Products	Mean Sum of Cross Products	Expected Sum of Cross Products
Between Sires	S-1	SCP_S	MCP_S	$Cov_W + kcov_s$
Progeny within sires	n.-S	SCP_W	MCP_W	Cov_W

S = number of sires

n_i = number of individuals within the ith sire.

n.. = total number of individuals.

Estimating cov_W and cov_S

$cov_W = MCP_W$

$cov_S = (MCP_S - MCP_W)/k$

Estimating correlation.

General formula for estimating correlation was

$$r = \frac{\text{cov}_{xy}}{\sqrt{\sigma^2{}_x \sigma^2{}_y}}$$

Estimating genetic correlation from sire component of variance

$$r_R = \frac{4cov_{sxy}}{2Var_{sx} * 2Var_{sy}}$$

$$S.E \quad of \quad r_g = \frac{1 - r^2{}_g}{\sqrt{2}} \sqrt{\frac{S.E \quad h^2_{(x)} \quad X \quad S.E \quad h^2_{(y)}}{h^2_{(x)} \quad h^2_{(y)}}}$$

Estimating environmental correlation from sire component of variance

$$r_e = \frac{cov_{wxy} + 3cov_{sxy}}{Var_{wx} - 3(Var_{sx})(Var_{sy}) - Var_{sy}}$$

Estimating phenotypic correlation from sire component of variance

$$r_p = \frac{cov_{wxy} + cov_{sxy}}{Var_{wx} + (Var_{sx})(Var_{sy}) + Var_{sy}}$$

3.8.4 ***Estimating expected and realized response to selection***

Expected genetic progress in one generation of selection was estimated by:

$G = h^2 X SD$

Where h^2 is the heritability estimate calculated using variance component analysis.

SD is the selection differential which refers to the superiority or inferiority of those selected for parent, P_s as compared to the average of the population, P from which the breeding animals were selected.

$$SD = (\overline{P}_S - \overline{P}) \quad SD = (P_S - P)$$

Where $\overline{P}_S$ was the average of the selected individuals

$\overline{P}$ is the average of the population before selection

3.8.5 Estimation of expected and realized response to selection for primary trait under selection

Expected response to selection for egg production to 280 days was calculated as per Falconer (1960) using the formula

Response (R) = $ih^2\sigma_p$

Where

i = intensity of selection

h^2 = heritability

σ_p = phenotypic standard deviation of the trait under selection

Realised phenotypic response per generation was calculated for the selected trait by the regression of generation means on generation number.

The estimation of genetic response (G) were estimated in a manner similar to phenotypic response after correction of selected line means for control deviation, the mean of selected line from mean of control line using the following formula:

$G = (S_n - C_n) - (S_0 - C_o)$

Where S and C represent selected and control lines, respectively and the subscripts represent the generations. In this manner, environmental effects between generation were corrected since it is assumed that an environment has similar effects on selected and control lines within generation.

Realized responses were estimated using the formula below:

For phenotypic response

$R_p = S_t - S_0$

$$t = \frac{b}{SE(b)}$$

with n-2 degree of freedom where there were n pairs of observation

Selection Differential

Selection differential is the difference between the mean performance of selected individual ($\overline{P}_{XS}$) and the mean of the population before selection from which the individuals were selected ($\overline{P}_X$). When selection differential is divided by phenotypic standard deviation (σ_p) of the trait under selection, the standardized selection differential or selection intensity (i) is obtained.

Thus

$$i = \frac{P_{x_s} - P_{\bar{x}}}{\sigma_P} = \frac{S}{\sigma_P}$$

The effective selection differentials were calculated by weighting each parent according to the number of offspring they produced which survived and contributed to the sampling variance of the next generation.

The effect of natural selection over artificial selection was calculated from the ratio of effective selection differential to expected selection differential (Falconer 1960).

Effective population size and rate of inbreeding

Effective population size N_e in each parental generation for the selected group was computed as per the formula described by Wright (1931).

$$N_e = \frac{4N_m N_f}{N_m + N_f}$$

Where

N_m = number of male parents and N_f = number of female parents

However, because of the possibility of each parent contributing unequal number of progeny Gowe et. al. (1959) suggested a modified formula which included a term for variance of family size. This was achieved by weighting the number of male and female parents with their respective variance in family size. By this formula, the effective number of individuals in each parental generation was calculated for the selected group as follows:-

$$\frac{1}{M_e} = \frac{1}{M_e}\left(1+\frac{\sigma_M{}^2-\bar{n}_M}{\bar{n}_M{}^2}\right)$$

and

$$\frac{1}{F_e} = \frac{1}{F_e}\left(1+\frac{\sigma_F{}^2-\bar{n}_F}{\bar{n}_F{}^2}\right)$$

where

$\bar{n}_M$ = mean number of progeny per sire

$\bar{n}_F$ = mean number of progeny per dam

σ^2_M = the variance in number of progeny per sire

σ^2_F = the variance in number of progeny per dam

For the control line N_e was estimated as

$$N_e = \frac{16N_mN_f}{3N_m+N_f}$$

Where N_m and N_F are the numbers of male and female breeders respectively.

The increase in coefficient of inbreeding per generation due to finite

population size was calculated as per Wright (1931) using the following formula.

$$\Delta F = \frac{1}{8N_M} + \frac{1}{8N_F} = \frac{N_M + N_F}{8N_M N_F}$$

For the control line, inbreeding coefficient per generation was computed as per formula suggested by Gowe et al.,(1959) as

$$\Delta F = \frac{3}{32N_M} + \frac{1}{32N_F}$$

3.8.6 MULTILOCATIONAL TESTING OF THE COMMERCIAL LAYER RESULTING FROM THE SELECTION EXPERIMENT

After the fifth generation of selection, the commercial layers resulting from the selection experiment were tested in various ecological zones of Nigeria using the following procedures.

Choice of Location:

Nine institutions were selected in such a way as to cover all the ecological zones of Nigeria. The following institutions were finally used to test the commercial layers: University of Agriculture, Abeokuta, University of Ibadan, Obafemi Awolowo University Ile-Ife, Federal university of Agriculture Umudike, Abubakar Tafawa Balewa University, Bauchi, University of Maiduguri, University of Ilorin, University of Nigeria, Nsukka. Meetings were held with the representatives of these institutions and memorandum of understanding (MOU) were prepared and signed by NAPRI and the institutions. This MOU contained detailed management of the commercial chicks to be given to various institutions. In addition to the commercial chicks being given to them, money was disbursed to the institution to raise the chicks up to point of lay. The record expected to be kept by each institution include age at first egg, age at 5% production, age at 50% production, livability, hen housed production, hen day production, body weight at 20 wks and at 40 weeks , body weight at 72 weeks . The institutions were expected to

submit their reports quarterly and one final reports each. The result of this commercial test was then summarized.

CHAPTER 4

RESULTS

4.1 Effective Population size and Inbreeding.

The number of pullets housed at about 18 weeks per population ranged between 323 and 1000 per generation for each of the population (Table 4.) The effective number of parents in each generation averaged 174 and 187 for male and female line populations, respectively. The increase in coefficient of inbreeding per generation due to finite population size was calculated as averaging 0.005 and 0.005 for male and female line, respectively (Table 4). This is an indication that inbreeding could not have depressed the economic performance of the populations under selection.

4.2 Variance components

The basis of selection is variation, which is measured by variance. The total variation observed within a population can be partitioned into various components depending on whether full model (whereby sire and dam were considered as potential source of variation) or reduced model (whereby only sire was considered as potential source of variation) is used in the analysis of variance. For the purpose of this work, both full and reduced models were used to determine the contribution of sire, dam and maternal effects.

Tables 7 and 13 showed the variance components obtained using full model (hierarchical) for male and female line populations, respectively. These are absolute values. Along side with these tables are Tables 11 and 14 showing the percent of the

variance components from sire, dam and sire+dam as percentages of total variance. These tables set the unit of measurement for all traits to the same basis. Where the calculated variance component is negative, the component is set at zero. Hence the dam components for female line were set to zero in 1992, 1993 and 1994 (Tables 13) for ASM. In the male line, the sire component of variance for ASM was set at 0 for 1994 (Table 7). Other variance components set to 0 in the male line population are dam components of variance for egg number in 1995 and dam components for rate of lay in 1991 and 1995 (Table 7).

When the variance component was estimated using one way analysis of variance model with resemblance based on sire, negative variance (i.e. 0 variance components) was virtually eliminated (Tables 10, 11, 17 and 18).

4.3 Maternal effects

Tables 8, 9, 15 and 16 showed the degree of maternal effect or sex linkage effect. In the female line, egg weight, and body weight at 40 weeks were affected by joint maternal environment during the first 3 generation of selection after which the two traits were mainly affected by sex linkage. The age at sexual maturity (ASM), egg numbers, rate of lay and egg mass were not affected by joint maternal environment in

the female line. For the male line, there was no indication of maternal effect in any of the traits.

In the male line population, egg weight was highly affected by sex linkage, which gradually reduced until during 5th generation (1995) (Tables 8 and 9) when maternal effect was observed. In the female line the opposite was the case (Tables 15 and 16). Except for 1993, maternal environments and other gene effects such as overdominance, dominance and epistasis mainly affected expression of age at sexual maturity. In the female line, egg weight and body weights were affected by maternal environment up to the third generation of selection after which they ceased to be affected. However, a trend was noticed in the case of the egg mass, the sex linkage effect reduced to almost 0% in fourth generation. By fifth generation, maternal effect was noticed.

4.4 Heritability Estimates

Tables 19 and 20 show the heritability estimates of male and female lines respectively obtained from sire, dam and sire+dam components of variance. Tables 28 and 30 showed the heritability estimates obtained using one model from sire components of variance. In the female line, heritability estimate could not be determined for ASM in 1995. This is due to an outbreak of Newcastle disease that killed a large number of the birds being monitored.

Heritability estimates were lower in 1994 and 1995 for most traits than the estimated values for the earlier generation of the selection experiment.

The results also showed that the standard error associated with heritability estimated from dam component of variance were consistently higher than those estimated from sire component.

When only sire information was used to for genetic parameter estimation, there were tremendous improvements in the values of heritability estimates. Tables 28 and 30 shows the heritability estimates obtained using only sire information for analysis of variance. Except for body weight and ASM in 1994, standard error associated with heritability estimates were considerably lower than the heritability. Pooled heritability estimates were also computed as shown in the heritability tables.

Table 4. *Effective Number of sires, dams and parents and expected inbreeding for* birds reaching breeding age

Line	Gen	No. of ♀ tested	Sires (Nm)	Dams (Nm)	Effective Parents		Inbreeding ΔF
					Ne (Wright)	Ne (Gowe)	
Male	1	696	34	148	110.6	185.0	0.0045
	2	979	27	180	93.9	192.0	0.0053
	3	917	28	188	97.5	194.9	0.0051
	4	803	27	142	90.7	161.6	0.0055
	5	941	28	121	91.0	137.6	0.0055
	Average		29	156	96.7	174.2	0.0052
	Cumulative F						0.0259
Female	1	845	35	234	121.8	243.0	0.0041
	2	1000	31	235	109.5	256.9	0.0046
	3	1000	31	224	108.9	202.9	0.0046
	4	998	28	206	98.6	82.3	0.0051
	5	1000	33	209	114.0	150.2	0.0044
	Average		32	222	110.6	187.9	0.0046
	Cumulative F						0.0228

Table 5. Average performance by generation, population and traits of male line selected for improved egg production

Trait	Group	1991 Mean	1991 Std Dev	1992 Mean	1992 Std dev	1993 Mean	1993 Std Dev	1994 Mean	1994 Std Dev	1995 Mean	1995 Std Dev	b_p	b_i
Egg280D[a]	Whole[1]	35.34	15.43	35.25	16.72	27.99	12.65	39.15	14.11	34.67	14.74	0.19	
	Selected[2]	48.06	10.87	50.74	11.5	38.38	10.16	50.94	8.53	41.47	11.78		-0.42
	Control[3]	34.18	14.36	35.56	16.63	25.38	13.37	39.49	15.83	35.63	13.5	-10.8	
ASM[b]	Whole	203.13	18.55	207.73	22.09	222.34	18.57	214.08	17.29	212.33	22.58	2.95	
	Selected	194.42	12.97	195.44	16.62	212.33	15.55	207.72	10.92	207.21	14.12		-0.21
	Control	200.55	15.6	205.77	20.06	221.31	20.6	212.54	14.39	210.61	13.74	7.65	
Egg wt[c]	Whole	55.99	4.24	54.88	3.65	55.97	4.08	55.92	4.64	48.29	3.69	-1.13	
	Selected	55.61	4.09	54.39	3.25	55.93	3.92	55.66	4.2	48.16	3.64		-0.43
	Control	55.61	4.43	54.65	3.82	54.45	4.76	56.25	3.94	50.8	3.13	0.55	
BWT40[d]	Whole	1559.6	183.01	1726	213.3	1659.2	229.64	1708.4	223.29	1466	200	20	
	Selected	1601.5	188.32	1754.8	216.65	1687.5	229.87	1723.8	221.99	1600	228		-34.45
	Control	1685.7	223.86	1697.6	189.55	1704.9	177.14	1659.8	252.56	1430	192.63	-54	
Eggmass[e]	Whole	2039.4	795.27	2025.1	838.33	1628.9	648.4	2306	692	1732.2	659.76	-21.8	
	Selected	2663.6	593.83	2763.6	608.58	2146	538.91	2837.6	517.63	1996.6	597.12		46.76
	Control	1909.6	747.86	1996.4	824.36	1472.8	684.87	2291.4	600	1829.15	642.72		
Rate[f]	Whole	46.62	15.35	50.13	20.2	50	16.79	61.87	17.15	52.42	15.68	1.9	
	Selected	56.72	10.13	61.06	13.7	57.6	11.52	71.08	11	57.85	11.22		0.50
	Control	43.63	13.35	48.26	19.56	45.47	21.6	60.21	17.68	51.8	16.09	-6.98	

[1]Whole = Population before outstanding producers were selected;
[2]Selected = Population of the selected group
[3]Control = Population of the control group.
a Egg number to 280 days
b Age at sexual maturity
c Matured egg weight
d Body weight at 40 weeks of age
e Rate of lay
f Egg mass

Table 6. Average performance by generation, *population and* traits of female line selected for improved Egg production

		1991		1992		1993		1994		1995			
Trait	Group	Mean	Std Dev	Mean	Std dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	b_p	b_c
Egg280D	Whole[1]	30.79	14.96	30.74	16.31	25.34	13.12	40.74	14.73	31.7	13.51	1.67	
	Selected[2]	44.31	9.77	47.41	10.19	37.03	9.68	51.25	10.37	37.37	10.2		3.14
	Control[3]	38.31	13.33	28.37	17.02	19.94	11.13	34.39	14.87	25.52	11.2	0.68	
ASM	Whole	208.49	28.64	218.26	21.01	224.14	16.8	212.23	10.78	217.41	19.93	1.01	
	Selected	197.56	12.91	203.58	12.78	214.52	17.24	206.98	8.862	207.22	9.12		-3.92
	Control	201.48	14.74	202.84	19.25	237.35	20.03	215.4	13.15	220.74	10.64	7.71	
Egg wt	Whole	43.35	17.27	55.73	3.71	55.64	4.26	54.85	4.36	48.86	3.46	-1.21	
	Selected	54.17	9.77	55.11	3.57	54.87	3.84	54.63	4.8	48.91	3.19		0.89
	Control	46.72	13.77	54.83	5.66	54.8	5.92	55.03	3.73	49.24	3.42	0.03	
BWT40	Whole	1603.5	192.66	1777.2	218.61	1834.3	300.39	1703.2	288.48	1414.73	248.63	-28.6	
	Selected	1607.7	182.72	1808.6	209.87	1908.8	282.08	1722.8	266.14	1440	228		6.12
	Control	1614.5	198.91	1667.9	209.63	1687	194.56	1614.7	256.37	1446	180	-0.52	
Eggmass	Whole	1828.7	768.3	1833	824.28	1485	682.49	2376.2	722.59	1629.05	595.14	47.61	
	Selected	2451.5	540.81	2618.3	541.48	2044.8	531.25	2808.9	604.14	1826.76	501.4		121.74
	Control	2104.7	696.27	1644.7	917.24	1177.5	555.11	2169.8	732.44	1305.3	522.74	14.44	
Rate	Whole	43.35	17.27	50.38	19.83	49.96	16.59	62.6	17.24	53.83	16.46	2.34	
	Selected	54.17	9.77	62.25	10.53	58.55	11.87	70.35	12.05	58.47	13.36		1.52
	Control	48.72	13.77	36.83	19.89	46.9	21.81	59.41	17.29	46.41	18.63	0.83	

[1]Whole = Population *before* outstanding producers were selected;
[2]Selected = Population of the selected group
[3]Control = Population of the control group.

Table 7 Variance Component of male line by year

Year	Source	Traits					
		ASM[1]	Egg280d[2]	EWTAV[3]	BWT40[4]	Rate of Lay[5]	Eggmass[6]
	Sire	19.75	10.59	1.28	1734.87	7.22	24570.58
	Dam	25.13	7.37	0.40	3320	0.00	15957
1991	Sire+Dam	44.88	17.96	1.68	5055	7.22	40528
	Within	255.77	174.66	15.19	26541	183.05	549525
	Total	300.65	192.62	16.88	31597	190.27	590052
	Sire	15.73	13.47	1.42	5730	10.44	34713
	Dam	35.17	11.25	0.63	3065	9.67	34969
1992	Sire+Dam	50.91	24.71	2.05	8796	20.11	69681
	Within	645.66	208.41	11.32	29874	273.84	614724
	Total	696.56	233.12	13.37	38670	293.95	684408
	Sire	27.62	3.77	2.06	865	7.40	16189
	Dam	14.51	9.26	1.38	1294	3.04	29782
1993	Sire+Dam	42.13	13.03	3.44	2160	10.44	45971
	Within	280.64	138.96	12.29	41333	269.57	418893
	Total	322.76	151.98	15.73	43493	280.01	464864
	Sire	0.00	8.11	0.87	43	3.11	25385
	Dam	203.28	15.65	0.71	1613	38.17	48973
1994	Sire+Dam	203.28	23.76	1.57	1656	41.28	74358
	Within	718.43	161.62	15.54	40572	289.45	521084
	Total	921.71	185.38	17.12	42228	330.73	595441
	Sire	5.18	14.46	0.81	2205	17.78	52009
	Dam	18.96	0.00	1.36	782	0.00	7455
1995	Sire+Dam	24.14	14.46	2.17	2986	17.78	39465
	Within	193.46	163.52	10.94	36297	239.55	367505
	Total	217.61	177.98	13.11	39283	257.34	406970

1 Egg number to 280 days 2 Age at sexual maturity 3 Matured egg weight 4 Body weight at 40 weeks of age
5 Rate of fay 6 Egg mass

Table 8. Maternal effect (+) or sex linkage (-) in Male line

Year	asm[1]	Egg280d[2]	ewtav[3]	Bwt40[4]	Lay rate[5]	eggmass[6]
1991	5.39	-3.22	-0.88	1585.3	-7.22	-8613.6
1992	19.44	-2.22	-0.79	-2666.09	-0.78	256.03
1993	-13.11	5.5	-0.67	428.92	-4.36	13593.42
1994	203.28	7.54	-0.16	1569.62	35.05	23588.35
1995	13.78	-14.46	0.55	-1423.24	-17.78	-24553.9

1 Egg number to 280 days 2 Age at sexual maturity 3 Matured egg weight 4 Body weight at 40 weeks of age 5 Rate of lay 6 Egg mass

Table 9. Maternal effect (+) or sex linkage (-) as % of total variance in the Male line

Year	Asm[1]	egg280d[2]	ewtav[3]	bwt40[4]	lay Rate[5]	eggmass[6]
1991	1.79	-1.67	-5.24	5.02	-3.8	-1.46
1992	2.79	-0.95	-5.89	-6.89	-0.26	0.04
1993	-4.06	3.62	-4.29	0.99	-1.56	2.92
1994	22.05	4.07	-0.92	3.72	10.6	3.96
1995	6.33	-8.13	4.17	-3.62	-6.91	-6.03

1 Egg number to 280 days 2 Age at sexual maturity 3 Matured egg weight 4 Body weight at 40 weeks of age 5 Rate of lay 6 Egg mass

Table 10. Variance Components by traits and generation from using sire information only in the Male line

		Year				
	Source	1991	1992	1993	1994	1995
Asm[1]	Among sire	25.7	16.6	31.5	7.4	7.1
	Within	268.6	694.7	295.2	857.5	202.8
	Total	294.3	711.4	326.7	864.9	209.9
Egg280d[2]	Among sire	11.3	13.7	5.1	8.8	15.9
	Within	178.8	219.5	145.1	169.2	161.6
	Total	190.1	233.2	150.2	178.1	177.5
Ewtav[3]	Among sire	1.6	1.7	2.3	1.1	1.0
	Within	15.6	11.8	13.6	16.5	11.7
	Total	17.2	13.5	15.9	17.5	12.7
Bwt40[4]	Among sire	2251.8	6769.6	1217.2	498.3	3598.7
	Within	27886.7	31202.3	43185.0	42606.8	34915.3
	Total	30138.4	37971.9	44402.2	43105.1	38514.0
Lay rate[5]	Among sire	6.8	11.3	6.3	7.7	25.1
	Within	181.5	282.2	269.7	305.9	233.6
	Total	188.3	293.5	276.0	313.6	258.7
Eggmass[6]	Among sire	27314.9	35169.0	21745.1	28285.1	40120.3
	Within	564408.0	649067.7	439791.3	546827.8	60889.2
	Total	591722.9	684236.7	461536.4	575112.9	101009.5

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 11 Variance Components by traits and generation from using sire information only in the female line

Traits	Source	Year				
		1991	1992	1993	1994	1995
ASM[1]	Among sire	25.7	16.6	31.5	7.4	7.1
	Within	268.6	694.7	295.2	857.5	202.8
	Total	294.3	711.4	326.7	864.9	209.9
Eggno[2]	Among sire	11.3	13.7	5.1	8.8	15.9
	Within	178.8	219.5	145.1	169.2	161.6
	Total	190.1	233.2	150.2	178.1	177.5
EWTAV[3]	Among sire	1.6	1.7	2.3	1.1	1.0
	Within	15.6	11.8	13.6	16.5	11.7
	Total	17.2	13.5	15.9	17.5	12.7
BWT40[4]	Among sire	2251.8	6769.6	1217.2	498.3	3598.7
	Within	27886.7	31202.3	43185.0	42606.8	34915.3
	Total	30138.4	37971.9	44402.2	43105.1	38514.0
Rate[5]	Among sire	6.8	11.3	6.3	7.7	25.1
	Within	181.5	282.2	269.7	305.9	233.6
	Total	188.3	293.5	276.0	313.6	258.7
Mass[6]	Among sire	27314.9	35169.0	21745.1	28285.1	40120.3
	Within	564408.0	649067.7	439791.3	546827.8	60889.2
	Total	591722.9	684236.7	461536.4	575112.9	401009.5

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 12. Variance component as % of total variance due to sire group in the Male Line

Traits	Source	Year				
		1991	1992	1993	1994	1995
ASM[1]	Among Sire	8.7	2.3	9.6	0.9	3.4
	Within	91.3	97.7	90.4	99.1	96.6
	Total	100.0	100.0	100.0	100.0	100.0
Eggno[2]	Among Sire	5.9	5.9	3.4	5.0	8.9
	Within	94.1	94.1	96.6	95.0	91.1
	Total	100.0	100.0	100.0	100.0	100.0
EWTAV[3]	Among Sire	9.2	12.6	14.6	6.1	7.5
	Within	90.8	87.4	85.4	93.9	92.5
	Total	100.0	100.0	100.0	100.0	100.0
BWT40[4]	Among Sire	7.5	17.8	2.7	1.2	9.3
	Within	82.2	97.3	98.8	90.7	92.5
	Total	100.0	100.0	100.0	100.0	100.0
Lay Rate[5]	Among Sire	3.6	3.8	2.3	2.5	9.7
	Within	96.4	96.2	97.7	97.6	90.3
	Total	100.0	100.0	100.0	100.0	100.0
Eggmass[6]	Among Sire	4.6	5.1	4.7	4.9	10.0
	Within	95.4	94.9	95.3	95.1	90.0
	Total	100.0	100.0	100.0	100.0	100.0

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 13. Variance components by year of female line selected for improved egg production

Year	source	Traits					
		ASM[1]	EGG280D[2]	EWTAV[3]	BWT40[4]	LAY RATE[5]	EGG-MASS[6]
	sire	18.36	20.65	1	0	11.96	56928
	dam	10.12	0	1.51	5575.5	8.15	0
1991	sire+dam	28.48	20.65	2.51	5575.5	20.11	56928
	within	386.28	203.59	12.55	27731	288.93	627075.81
	total	414.76	224.23	15.06	33307.15	309.04	684003.81
	sire	16.39	18.37	0.79	2855.9	19.39	54633.69
	dam	0	8.72	1.62	6897.89	2.2	24734.11
1992	sire+dam	16.39	27.09	2.41	9753.79	21.59	79367.79
	within	377.63	181.69	10.74	31773.77	332.4	550254.88
	total	394.02	208.78	13.15	41527.57	353.99	629622.67
	sire	14.49	10.04	1.57	3349.13	9.97	31574.35
	dam	32.51	6.01	1.53	5694.17	11.57	12671.98
1993	sire+dam	47	16.05	3.1	9043.3	21.54	44246.33
	within	234.89	121.19	12.46	70739.83	264.33	385960.65
	total		281.89	137.24	15.56	79783.13	285.87
	sire	8.05	8.6	1.19	2930.21	7.83	22153.74
	dam	0	2.33	0.32	307.87	3.32	18970.09
1994	sire+dam	8.05	10.93	1.51	3238.08	11.14	41123.83
	within	109.02	180.18	16.83	72569.02	291.38	545905.46
	total	117.06	191.12	18.34	75807.1	302.52	587029.28
	sire	0	4.97	0.77	2281.24	9.81	10980.17
	dam	0	2.9	0.04	672.96	0	16750.57
1995	sire+dam	0	7.87	0.81	2954.2	9.81	27730.74
	within	483.41	129.28	10.47	46735.41	285.79	307965.32
	total	483.41	137.15	11.28	49689.61	295.6	335696.06

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 14. Variance components as % of total variance by year in the female line *selected for improved egg production*

Year	Source	Traits					
		asm[1]	egg280d[2]	Ewtav[3]	bwt40[4]	lay rate[5]	eggmass[6]
	sire	4.4	9.2	6.6	0.0	3.9	8.3
	dam	2.4	0.0	10.0	16.7	2.6	0.0
1991	sire+dam	6.9	9.2	16.7	16.7	6.5	8.3
	within	93.1	90.8	83.3	83.3	93.5	91.7
	total	100.0	100.0	100.0	100.0	100.0	100.0
	sire	4.2	8.8	6.0	6.9	5.5	8.7
	dam	0.0	4.2	12.3	16.6	0.6	3.9
1992	sire+dam	4.2	12.1	18.3	23.5	6.1	12.6
	within	95.8	81.0	81.7	76.5	93.9	87.4
	total	100.0	100.1	100.0	100.0	100.0	100.0
	sire	5.1	7.3	10.1	4.2	3.5	7.3
	dam	11.5	4.4		9.8	7.1	4.1
1993	sire+dam	16.7	11.7		19.9	11.3	7.5
	within	83.3	88.3	80.1	88.7	92.5	89.7
	total	100.0	100.0	100.0	100.0	100.0	100.0
	sire	6.9	4.5	6.5	3.9	2.6	3.8
	dam	0.0	1.2	1.7	0.4	1.1	3.2
1994	sire+dam	6.9	5.7	8.2	4.3	3.7	7.0
	within	93.1	94.3	91.8	95.7	96.3	93.0
	total	100.0	100.0	100.0	100.0	100.0	100.0
	sire	0.0	3.6	6.8	4.6	3.3	3.3
	dam	0.0	2.1	0.4	1.4	0.0	5.0
1995	sire+dam	0.0	5.7	7.2	6.0	3.3	8.3
	within	100.0	94.3	92.8	94.1	96.7	91.7
	total	100.0	100.0	100.0	100.0	100.0	100.0

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 15 Maternal effect(+) or sex linkage(-) of Female Line selected for improved egg number

Year	ASM[1]	EGG280D[2]	EWTAV[3]	BWT40[4]	LAY RATE[5]	EGGMASS[6]
1991	-8.24	-20.65	0.51	5575.5	-3.82	-56928
1992	-16.39	-9.65	0.83	4041.99	-17.19	-29899.6
1993	18.02	-4.02	-0.04	2345.05	1.6	-18902.4
1994	-8.05	-6.27	-0.88	-2622.34	-4.51	-3183.65
1995	0	-2.07	-0.72	-1608.28	-9.81	5770.4

1 Egg number to 280 days 2 Age at sexual maturity 3 Matured egg weight
4 Body weight at 40 weeks of age 5 Rate of lay 6 Egg mass

Table 16. Maternal effect (+) or sex linkage (-) as % of total variance in the female line selected for improved egg number

Year	ASM[1]	EGG280D[2]	EWTAV[3]	WT40[4]	LAY RATE[5]	EGGMASS[6]
1991	-1.99	-9.21	3.39	16.74	-1.24	-8.32
1992	-2.09	-9.89	3.88	13.43	-1.08	-9.04
1993	-5.81	-7.03	5.33	5.07	-6.01	-6.95
1994	-6.88	-3.28	-4.8	-3.46	-1.49	-0.54
1995	0	-1.51	-6.38	-3.24	-3.32	1.72

1 Egg number to 280 days 2 Age at sexual maturity 3 Matured egg weight
4 Body weight at 40 weeks of age 5 Rate of lay 6 Egg mass

Table 17 Variance Component by traits, generation from paternal half sib model, in the Female Line selected for improved egg production

Traits	Source	Year				
		1991	1992	1993	1994	1995
ASM[1]	Among	19.89	16.45	18.93	8.10	0.00
	Within	394.87	375.90	262.97	107.35	390.58
	Total	414.76	392.36	281.90	115.45	390.58
Eggno[2]	Among	20.85	19.39	10.86	8.91	5.30
	Within	199.59	189.39	126.38	182.20	131.86
	Total	220.45	208.78	137.24	191.12	137.15
EWTAV[3]	Among	1.23	0.98	1.78	1.24	0.77
	Within	13.83	12.17	13.78	17.11	10.51
	Total	15.06	13.15	15.56	18.34	11.28
BWT40[4]	Among	505.47	3660.75	4127.23	2971.17	2356.49
	Within	32466.00	37867.04	75658.34	72835.97	47.28
	Total	32971.46	41527.79	79785.57	75807.14	49689.77
Rate of Lay[5]	Among	13.20	19.65	11.55	8.27	11.99
	Within	295.85	334.35	274.32	294.25	256.47
	Total	309.04	353.99	285.87	302.52	268.46
Eggmass[6]	Among	57283.30	57519.66	33305.96	24677.73	12853.21
	Within	620175.49	572103.81	396906.45	562354.07	322846.70
	Total	677458.79	629623.47	430212.41	587031.81	335669.90

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 18. Variance component as % of total variance due to sire group in the Female Line selected for improved egg production

Traits	Source	Year 1991	1992	1993	1994	1995
	Among	4.80	4.19	6.72	7.01	0.00
ASM[1]	Within	95.20	95.81	93.28	92.99	100.00
	Total	100.00	100.00	100.00	100.00	100.00
	Among	9.46	9.29	7.91	4.66	3.86
Eggno[2]	Within	90.54	90.71	92.09	95.34	96.14
	Total	100.00	100.00	100.00	100.00	100.00
	Among	8.17	7.42	11.42	6.74	6.84
EWTAV[3]	Within	91.83	92.56	88.56	93.26	93.16
	Total	100.00	100.00	100.00	100.00	100.00
	Among	1.53	8.82	5.17	3.92	4.74
BWT40[4]	Within	98.47	91.18	94.53	96.08	95.26
	Total	100.00	100.00	100.00	100.00	100.00
	Among	4.27	5.55	4.04	2.73	4.47
Rate of Lay[5]	Within	95.73	94.45	95.96	97.27	95.53
	Total	100.00	100.00	100.00	100.00	100.00
	Among	8.46	9.14	7.74	4.20	3.83
Eggmass[6]	Within	91.54	90.86	92.26	95.80	96.17
	Total	100.00	100.00	100.00	100.00	100.00

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 19 Heritability estimate from sire, dam and sire+dam components by year and trait in the Male line selected for improved egg production

Traits	source	1991		1992		1993		1994		1995		pooled	
		h2	se	h2	se	h2	se	h2	se	h2	se	h2	SE
ASM[1]	S	0.26	0.14	0.09	0.07	0.34	0.13	NA		0.1	0.13	0.15	0.05
	D	0.33	0.15	0.2	0.12	0.18	0.13	0.88	0.17	0.35	0.26	0.2	0.07
	S+D	0.3	0.09	0.15	0.06	0.26	0.07	0.44	0.09	0.22	0.11	0.18	0.04
EGGNO[2]	S	0.22	0.13	0.23	0.1	0.1	0.07	0.18	0.1	0.33	0.19	0.13	0.05
	D	0.15	0.2	0.19	0.12	0.24	0.13	0.34	0.15	0	0	0.16	0.07
	S+D	0.19	0.09	0.21	0.06	0.17	0.06	0.26	0.08	0.16	0.11	0.15	0.03
EWTAV[3]	S	0.3	0.15	0.43	0.15	0.52	0.18	0.2	0.11	0.25	0.17	0.24	0.06
	D	0.1	0.2	0.19	0.12	0.35	0.13	0.17	0.15	0.42	0.26	0.2	0.07
	S+D	0.2	0.09	0.31	0.07	0.44	0.08	0.18	0.07	0.33	0.12	0.24	0.04
BWT40[4]	S	0.22	0.13	0.59	0.19	0.08	0.06	0	0.05	0.22	0.16	0.07	0.04
	D	0.42	0.2	0.32	0.13	0.12	0.12	0.15	0.15	0.08	0.26	0.18	0.07
	S+D	0.32	0.09	0.46	0.08	0.1	0.05	0.08	0.06	0.15	0.11	0.16	0.03
RATE[5]	S	0.15	0.11	0.14	0.08	0.11	0.07	0.04	0.06	0.28	0.18	0.09	0.04
	D	0	0	0.13	0.12	0.04	0.12	0.46	0.26	0	0	0.08	0.08
	S+D	0.08	0.08	0.14	0.05	0.08	0.05	0.25	0.08	0.14	0.11	0.09	0.03
EGGMASS[6]	S	0.17	0.12	0.2	0.1	0.14	0.08	0.17	0.1	0.32	0.19	0.14	0.05
	D	0.11	0.2	0.2	0.12	0.26	0.13	0.33	0.15	0.07	0.26	0.16	0.07
	S+D	0.14	0.08	0.2	0.06	0.2	0.06	0.25	0.08	0.19	0.11	0.16	0.03

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 20. Heritability estimate from components of variance by year and traits in the Female line selected for improved egg production

Traits	source	1991		1992		1993		1994		1995		Pooled	
		h2	se	h2	se	h2	Se	h2	se	h2	se	h2	SE
ASM[1]	S	0.18	0.11	0.08	0.06	0.21	0.10	0.28	0.12	na		0.15	0.04
	D	0.10	0.17	0.17	0.09	0.46	0.14	na		na		0.23	0.07
	S+D	0.14	0.07	na		0.33	0.07	0.14	0.06	na		0.20	0.03
EGGNO[2]	S	0.18	0.11	0.26	0.07	0.29	0.12	0.18	0.09	0.15	0.15	0.23	0.04
	D	Na		0.35	0.14	0.18	0.13	0.05	0.12	0.09	0.28	0.18	0.08
	S+D	0.18	0.08	0.17	0.14	0.23	0.07	0.11	0.05	0.12	0.11	0.16	0.03
EwTAV[3]	S	0.27	0.13	0.37	0.07	0.40	0.15	0.26	0.11	0.27	0.18	0.34	0.05
	D	0.40	0.17	0.24	0.11	0.39	0.14	0.07	0.12	0.02	0.28	0.25	0.06
	S+D	0.33	0.08	0.49	0.15	0.40	0.08	0.17	0.06	0.14	0.11	0.29	0.04
BWT40[4]	S	na		0.47	0.08	0.17	0.09	0.16	0.08	0.18	0.16	0.27	0.04
	D	0.67	0.18	0.28	0.12	0.29	0.14	0.02	0.12	0.05	0.28	0.25	0.07
	S+D	0.34	0.08	0.66	0.15	0.23	0.07	0.09	0.05	0.12	0.11	0.21	0.03
LAY_RATE[5]	S	0.16	0.10	0.12	0.06	0.14	0.08	0.10	0.07	0.13	0.15	0.12	0.03
	D	0.11	0.17	0.22	0.10	0.16	0.13	0.04	0.12	na		0.14	0.06
	S+D	0.13	0.07	0.03	0.13	0.15	0.06	0.07	0.05	0.07	0.11	0.10	0.03
EGGMASS[6]	S	0.33	0.14	0.25	0.07	0.29	0.12	0.15	0.08	0.13	0.15	0.23	0.04
	D	na		0.35	0.14	0.12	0.13	0.13	0.12	0.20	0.28	0.19	0.08
	S+D	0.17	0.07	0.16	0.14	0.21	0.06	0.14	0.06	0.17	0.12	0.17	0.03

1 Egg number to 280 days
2 Age at sexual maturity
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table: 21 Yearly genetic correlation between egg number and other traits in female line under selection (from sire+dam components of variance)

Year	Asm[1]	ewtav[2]	bwt40[3]	rate[4]	mass[5]
1991	-0.73±0.43	-0.77±0.38	0.28±0.24	0.57±0.27	0.99±0.02
1992	-0.70±0.29	-0.23±0.19	0.10±0.17	0.82±0.10	0.98±0.01
1993	-0.85±0.32	0.19±0.19	-0.14±0.29	0.51±0.23	0.97±0.01
1994	0.08±0.19	-0.18±0.25	0.30±0.34	0.86±0.06	0.98±0.01
1995	-0.91±0.71	0.37±0.37	0.91±0.50	0.47±0.33	0.94±0.04
Pooled	-0.36±0.13	-0.08±0.11	0.17±0.11	0.82±0.05	0.98±0.005

1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table: 22 Yearly genetic correlation between egg number and other traits in male line under selection (from sire component of variance)

Year	asm[1]	ewtav[2]	bwt40[3]	rate[4]	mass[5]
1991	-0.77±0.42	-0.57±0.31	0.27±0.33	0.72±0.19	0.98±0.02
1992	-0.99±0.35	-0.38±0.25	-0.02±0.26	0.78±0.14	0.98±0.01
1993	-0.81±0.36	0.13±0.32	0.19±0.45	0.01±0.45	0.95±0.04
1994	NA	-0.16±0.36	-0.32±2.41	1.12±0.33	0.96±0.03
1995	-0.73±0.68	-0.22±0.36	0.46±0.33	1.06±0.05	1.00±0.01
Pooled	-0.86±0.21	-0.27±0.14	0.19±0.16	1.00±0.05	0.99±0.01

1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table: 23. Yearly genetic correlation between egg number and other traits in male line under selection (from dam component of variance)

Year	Asm[1]	ewtav[2]	bwt40[3]	rate[4]	mass[5]
1991	-0.70±1.36	-1.23±2.31	0.31±0.58	NA	1.00±0.06
1992	-0.53±0.65	0.02±0.49	0.29±0.37	0.88±0.25	0.98±0.02
1993	-1.01±1.00	0.25±0.37	-0.31±0.54	1.12±1.01	0.98±0.01
1994	0.09±0.25	-0.21±0.52	0.41±0.55	0.87±0.09	0.99±0.01
1995	NA	NA	NA	NA	NA
Pooled	-0.31±0.51	0.08±0.29	0.20±0.24	0.87±0.08	0.99±0.01

1 Age at sexual maturity 2 Matured egg weight 3 Body weight at 40 weeks of age
4 Rate of lay 5 Egg mass

Table: 24. Yearly genetic correlation between egg number and other traits in female line under selection (from sire component of variance)

Year	asm[1]	ewtav[2]	bwt40[3]	rate[4]	Mass[5]
1991	-0.47±0.46	-0.13±0.24	0.39±0.23	0.58±0.2	0.83±0.07
1992	-0.72±0.50	-0.41±0.18	-0.43±0.15	1.21±0.16	0.98±0.01
1993	-0.71±0.24	-0.37±0.17	0.30±0.20	0.72±0.11	0.98±0.01
1994	-0.75±0.47	0.15±0.29	0.49±0.37	0.89±0.08	0.97±0.02
1995	NA	0.90±0.71	0.87±0.67	-0.36±0.67	1.00±0.03
Pooled	-0.68±0.18	-0.25±0.10	0.01±0.10	0.85±0.06	0.98±0.01

1 Age at sexual maturity 2 Matured egg weight 3 Body weight at 40 weeks of age
4 Rate of lay 5 Egg mass

Table: 25 Yearly genetic correlation between egg number and other traits in female line under selection (from dam component of variance)

Year	asm[1]	ewtav[2]	bwt40[3]	rate[4]	mass[5]
1991	-0.94±0.34	-0.54±0.25	NA	0.85±0.12	1.03±0.01
1992	0.91±0.28	-0.37±0.26	-0.40±0.23	0.69±0.16	0.99±0.00
1993	-0.98±0.25	-0.14±0.25	0.62±0.23	0.77±0.13	0.98±0.01
1994	-0.77±0.28	-0.43±0.28	0.08±0.33	0.76±0.14	0.95±0.03
1995	NA	-0.13±0.44	0.50±1.10	0.13±	0.96±0.04
Pooled	-0.90±0.14	-0.35±0.12	0.10±0.14	0.85±0.06	1.00±0.01

1 Age at sexual maturity 2 Matured egg weight 3 Body weight at 40 weeks of age
4 Rate of lay 5 Egg mass

Table: 26 Yearly genetic correlation between egg number and other traits in female line under selection (from sire+dam component of variance)

Year	asm[1]	ewtav[2]	bwt40[3]	rate[4]	mass[5]
1991	NA	NA	NA	NA	NA
1992	NA	-0.52±0.48	-0.52±0.34	3.71±9.75	0.95±0.05
1993	-0.56±0.62	-0.68±0.50	-0.01±0.47	0.68±0.30	0.98±0.03
1994	NA	2.31±4.01	2.94±11.83	1.30±0.84	1.12±0.42
1995	NA	NA	2.97±9.60	NA	1.09±0.48
Pooled	-0.56±0.62	-0.58±0.34	-0.34±0.28	0.75±0.28	1.32±0.03

1 Age at sexual maturity 2 Matured egg weight 3 Body weight at 40 weeks of age
4 Rate of lay 5 Egg mass

Table 27 Yearly genetic, phenotypic and environmental correlations by trait in the male line using sire information of other traits with egg number

		Year				
Trait		1991	1992	1993	1994	1995
ASM[1]	g[a]	-0.78	-0.93	-0.85	-0.1	-0.56
	p[b]	-0.65	-0.33	-0.66	-0.01	-0.56
	e[c]	-0.61	-0.23	-0.63	-0.01	-0.59
Ewtav[2]	g	-0.56	-0.41	0.28	-0.13	0.2
	p	-0.11	-0.13	-0.12	-0.04	-0.18
	e	0.08	0.01	-0.33	-0.01	-0.36
bwt40[3]	g	0.18	0.01	0.26	-0.01	0.69
	p	0.18	0.16	0.19	0.04	0.07
	e	0.18	0.33	0.17	0.05	-0.28
rate[4]	g	0.65	0.78	0.03	0.88	0.96
	p	0.76	0.68	0.69	0.83	0.82
	e	0.79	0.66	0.77	0.83	0.74
Mass[5]	g	0.98	0.97	0.96	0.96	0.99
	p	0.98	0.99	0.98	0.97	0.98
	e	0.98	0.99	0.99	0.98	0.97

a G =genetic correlation
b P =phenotypic correlation
c E =environmental correlation
1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table 28 Yearly heritability estimates in male line based on sire information only

Trait	Year					Pooled
	1991	1992	1993	1994	1995	
ASM [1]	0.35±0.14	0.09±0.06	0.39±0.13	0.03±0.06	0.14±0.12	0.12±0.04
Eggno[2]	0.24±0.12	0.24±0.09	0.14±0.07	0.20±0.10	0.36±0.16	0.31±0.05
EWTAV[3]	0.37±0.14	0.50±0.15	0.59±0.16	0.25±0.11	0.30±0.15	0.43±0.07
BWT40[4]	0.30±0.	0.71±0.19	0.11±0.06	0.05±0.06	0.37±0.17	0.23±0.05
RATE[5]	0.14±0.10	0.15±0.07	0.09±0.06	0.10±0.07	0.39±0.17	0.19±0.04
MASS[6]	0.19±0.11	0.21±0.09	0.19±0.08	0.20±0.10	0.40±0.17	0.30±0.05

1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table 29. Yearly genetic, phenotypic and environmental correlation of other traits with egg number in female line using sire information

Trait		Year				
		1991	1992	1993	1994	1995
ASM[1]	G[a]	-0.85	-0.88	-0.90	-0.76	NA
	P[b]	-0.59	-0.66	-0.55	-0.56	-0.24
	E[c]	-0.50	-0.62	-0.40	-0.51	
ewtav[2]	G	-0.44	-0.37	-0.19	-0.33	0.02
	P	-0.11	-0.16	-0.05	-0.08	-0.01
	E	0.07	-0.05	0.04	-0.01	-0.01
bwt40[3]	G	-0.48	-0.40	0.54	0.14	0.14
	P	-0.02	0.17	0.19	0.03	0.12
	E	0.07	0.49	0.08	0.01	0.12
rate[4]	G	0.79	0.77	0.76	0.78	0.81
	P	0.73	0.51	0.76	0.88	0.82
	E	0.73	0.41	0.78	0.91	0.82
mass[5]	G	0.99	0.99	0.98	0.95	0.97
	P	0.99	0.99	0.98	0.97	0.98
	E	0.99	0.98	0.99	0.98	0.98

a G =genetic correlation
b P =phenotypic correlation
c E =environmental correlation
1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table 30. Yearly heritability estimates in female line based on sire information only

Trait	Year					Pooled
	1991	1992	1993	1994	1995	
ASM[1]	0.19±0.09	0.17±0.08	0.27±0.08	0.28±0.10	ND	0.31±0.05
Eggno[2]	0.38±0.13	0.37±0.12	0.32±0.11	0.19±0.08	0.15±0.11	0.31±0.05
EWTAV[3]	0.33±0.12	0.30±0.11	0.46±0.14	0.27±0.10	0.27±0.13	0.36±0.06
BWT40[4]	0.06±0.07	0.35±0.12	0.21±0.09	0.16±0.07	0.19±0.12	0.19±0.04
RATE[5]	0.17±0.09	0.22±0.09	0.16±0.08	0.11±0.06	0.18±0.11	0.19±0.04
MASS[6]	0.34±0.12	0.37±0.12	0.31±0.11	0.17±0.08	0.15±0.11	0.29±0.05

1 Age at sexual maturity
2 Egg number to 280 days
3 Matured egg weight
4 Body weight at 40 weeks of age
5 Rate of lay
6 Egg mass

Table 31. Correlation of egg number±SE with other traits in Male line selected for improved egg production

Year	ASM[1]	EWTAV[2]	BWT40[3]	LAY RATE[4]	EGGMASS[5]
1991	-0.78±0.41	0.20±0.37	0.69±0.33	0.65±0.23	0.98±0.02
1992	-0.93±0.35	-0.41±0.24	-0.41±0.26	0.78±0.14	0.97±0.02
1993	-0.85±0.29	0.28±0.29	0.26±0.37	0.03±0.44	0.96±0.03
1994	-0.10±0.66	-0.13±0.34	-0.01±0.58	0.88±0.12	0.96±0.03
1995	-0.56±0.37	0.20±0.37	0.69±0.28	0.96±0.06	0.99±0.01
Pooled	-0.75±0.17	-0.04±0.14	0.23±0.15	0.90±0.05	0.98±0.01

1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Eggmass

Table 32 Correlation of egg number with other traits in Female line selected for improved egg production

Year	Traits				
	ASM[1]	EWTAV[2]	BWT40[3]	LAY RATE[4]	EGGMASS[5]
1991	-0.85±0.32	-0.44±0.24	-0.48±0.45	0.79±0.13	0.99±0.01
1992	-0.88±0.28	-0.37±0.24	-0.40±0.22	0.77±0.13	0.99±0.01
1993	-0.90±0.22	-0.19±0.24	0.54±0.23	0.76±0.13	0.98±0.01
1994	-0.76±0.27	-0.33±0.28	0.14±0.32	0.78±0.13	0.95±0.03
1995	NA	0.02±0.43	0.14±0.47	0.81±0.16	0.97±0.03
Pooled	-0.85 0.13	-0.33 0.12	0.02 0.13	0.78 0.06	0.99±0.01

1 Age at sexual maturity
2 Matured egg weight
3 Body weight at 40 weeks of age
4 Rate of lay
5 Egg mass

Table 34. Estimated genetic and phenotypic change per generation

Trait	Male line		Female line	
	b_g	b_p	b_g	b_p
Eggno[1]	-0.43	0.19	3.14	1.67
ASM[2]	-0.21	2.95	-3.93	1.01
BWT40[3]	34.45	-12.18	-9.06	-28.60
EWTAV[4]	-0.64	-1.13	0.89	-1.21
EGGMASS[5]	-46.76	-21.81	0.01	47.61
Rate of lay[6]	-0.50	1.90	0.01	2.34

1 Age at sexual maturity
2 Matured egg weight
3Body weight at 40 weeks of age
4Rate of lay
5Egg mass

Table 35. Realised response and predicted gain for egg production up to 280 days

Line	Gen	Genetic Response	Predicted Gain	Realised/Predicted ratio
Maleline	1	1.16	3.05	0.38
	2	-0.31	3.71	-0.08
	3	2.61	1.45	-1.79
	4	-0.34	2.36	-0.14
	5	0.96	2.45	0.39
Femaleline	1	-7.52	5.14	-1.46
	2	2.37	6.17	0.38
	3	5.30	3.77	1.40
	4	6.35	2.00	3.18
	5	6.18	0.85	7.27

Table 36. The Expected correlated Response per generation E(CR), in trait i from selection for improved egg production to 280 days

Correlated	Line	h_x^2	h_i^2	r_g	$h_x.h_i.r_g$	δ	σ	$E(CR)_i$
ASM, d	Sire	0.15	0.27	-0.75	-0.13	0.78	19.82	-2.33
	Dam	0.16	0.17	-0.85	0.14	0.80	19.43	-2.17
Egg wt, g	Sire	0.15	0.29	-0.04	-0.07	0.78	4.06	-0.22
	Dam	0.16	0.28	0.33	0.00	0.80	6.61	0.01
Body wt, g	Sire	0.15	0.25	0.23	0.04	0.78	269.85	8.23
	Dam	0.16	0.25	0.02	0.07	0.80	298.07	16.61
Rate of lay	Sire	0.15	0.14	0.90	0.16	0.78	17.03	2.10
	Dam	0.16	0.11	0.78	0.09	0.80	17.48	1.21
Egg mass,	Sire	0.15	0.20	0.98	0.20	0.78	718.03	108.95
	Dam	0.16	0.19	0.99	0.18	0.80	718.56	102.01

δ = Intensity of selection
σ = Standard deviation

4.5 Average performance of the commercial layer resulting from the selection experiment

Table 37. The average performance of the commercial layer from the selection experiments.

Traits	Value
Rearing period livability 0-20wks, %	94
Age at first egg, days	136
Age at 50% production, days	168
Age at peak production, days	189
Percent at peak production,	88
Laying period livability (20-72 wks), %	90
Hen-housed egg production to 72 weeks, No.	278
Hen-day egg production to 72 weeks, No.	290
No. of weeks above 80% production	9
Body weight at maturity (40 wks), Kg	1.9
Average egg weight at maturity (40 wks), g	58.2
Body weight at 72 wks, kg	1.8

Table 37 showed the performance of the commercial hybrid averaged over many ecological zones in Nigeria. Age at first egg, 50% production and peak production reduced from 145, 170 and 200 days reported by Abubakar et al. (1995) to 136, 168 and 189 days, respectively. Hen housed and hen day egg production also increased from 233 and 240

eggs, respectively to 278 and 290 eggs. The rearing mortality and laying house mortality were similar in magnitude to those earlier reported.

Fig. 1: Egg production in selected and control lines

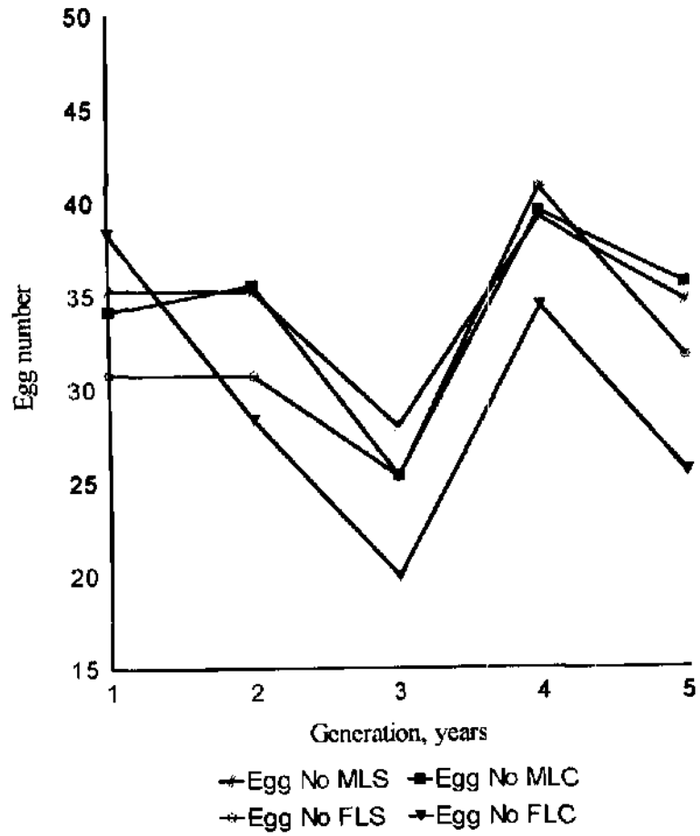


Fig. 2. Age at sexual maturity for selected and control lines.

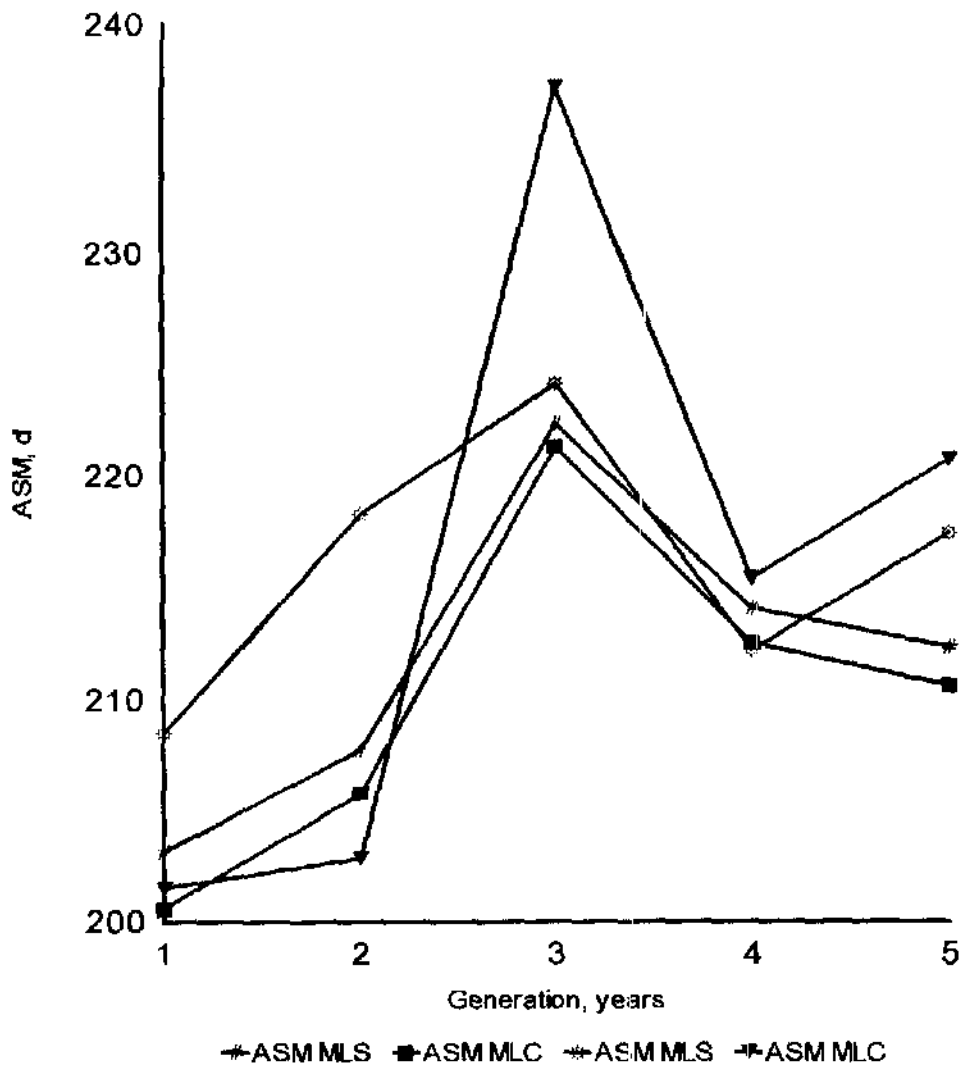


Fig. 3. Average egg weight for selected and control lines

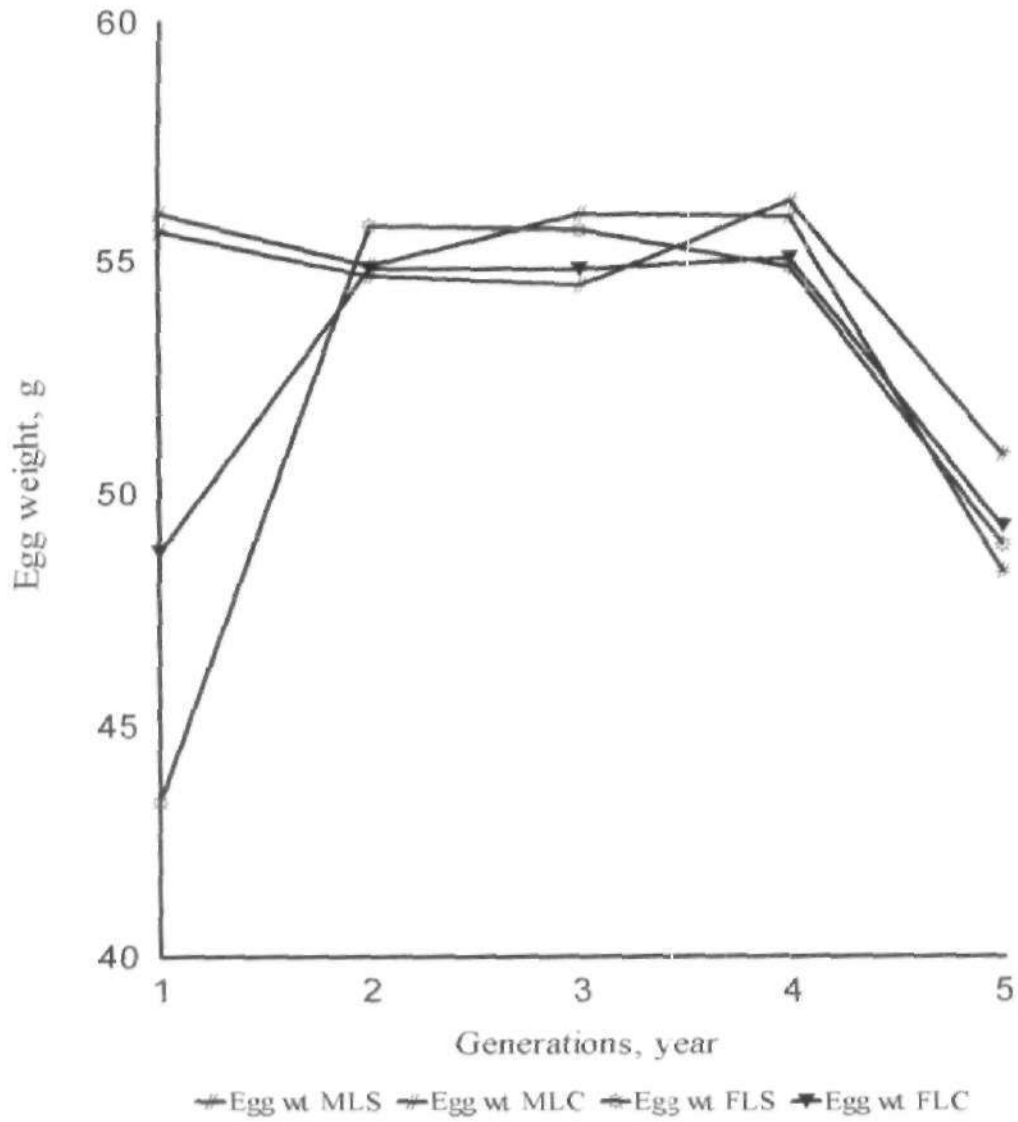


Fig. 4. Body weight at maturity for selected and control lines.

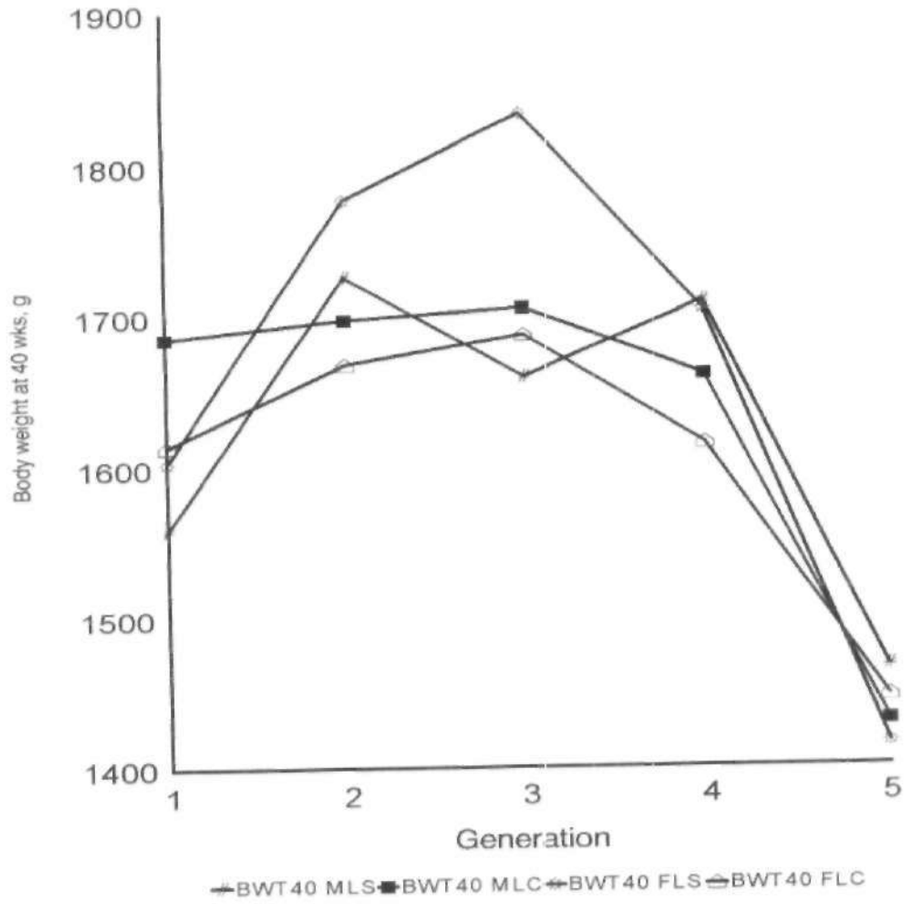


Fig. 5. Egg mass to 280days for selected and control lines

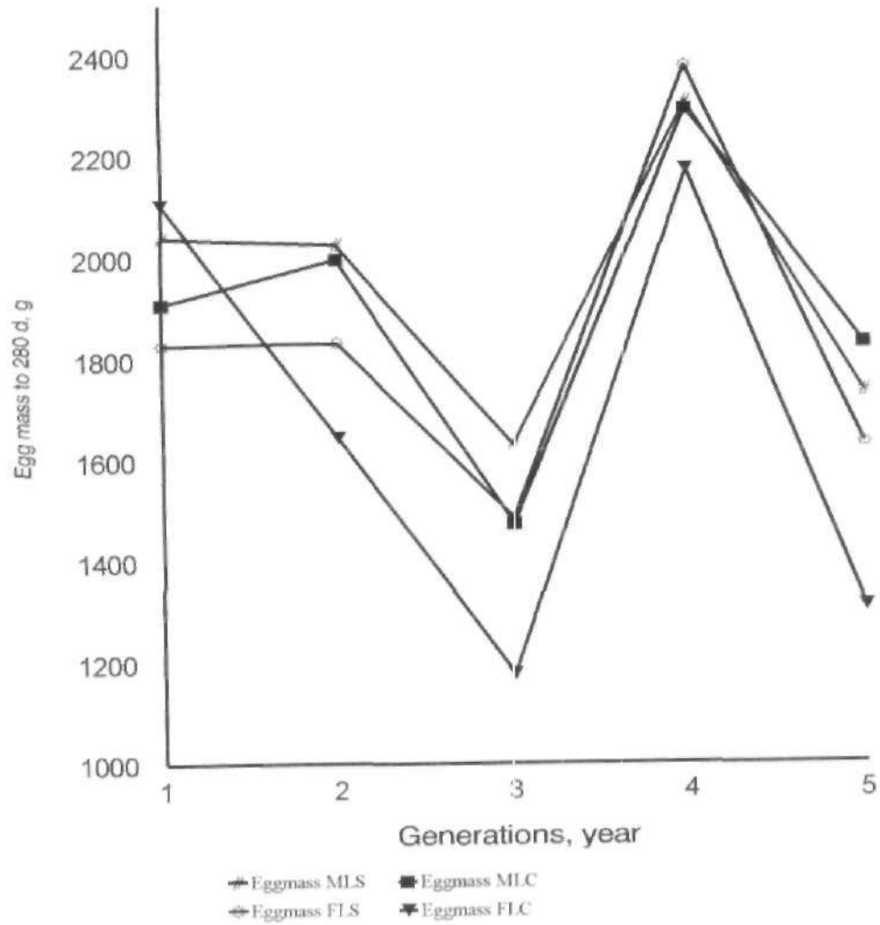
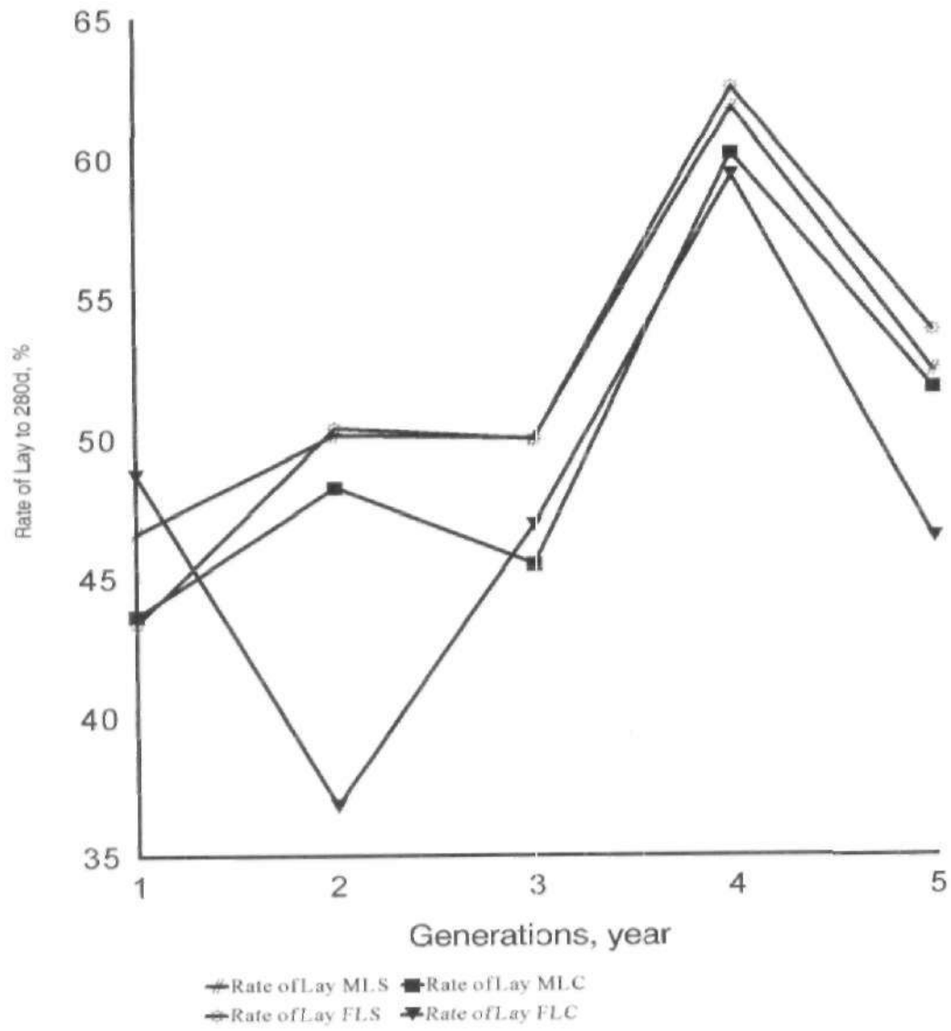


Fig. 6. Rate of lay (%) to 280days for selected and control lines



4.5 Genetic correlation

Tables 21 to 23 and 24 to 27 show the genetic correlation of egg number with other traits for male line and female line, respectively. Egg number was consistently negatively highly correlated with age at sexual maturity. The value of r_g were mostly higher than -0.60. the value of genetic correlations obtained from 1994 in male line was mostly unreliable as this could not be determined.

Egg number was highly and negatively correlated with mature egg weight when r_g was obtained from sire component of variance for both male and female lines. However, the standard errors associated with the estimates were higher than the actual estimates during the last two generations. The standard error associated with the genetic correlation of egg number with body weight at forty weeks was very high. Therefore less importance should be attached to the values.

Egg number was highly correlated with both rate of lay and egg mass to 280 days. This is expected because egg number is one of the two components that determined rates of lay and egg mass. Rate of lay is determined by age at first egg and number of egg laid to 280 days. Similarly egg mass was obtained by multiplying egg number with average mature egg weight. Hence improving egg number will be expected to lead to improvement of rate and mass.

4.6 Genetic parameter estimation using one way analysis of variance models

Tables 27 and 29 showed genetic, phenotypic and environmental correlations of various traits with egg number using sire component of variance. The r_g, r_p and r_e between egg number and ASM were negative and high throughout the period of the selection experiment for both male and female lines.

The r_g and r_e of egg number with egg weight were negative during the first two generations. Phenotypic correlations were consistently negative and low throughout for both male and female lines. The r_e was initially positive and later became negative after 2 and 3 generations of selection in male line and female line, respectively.

Genetic correlation of egg number with body weight was high and negative during the first 2 generations but became positive subsequently. Although r_e was negative in the first generation, it became positive from second generation onward in the female line. In the male line, r_g with egg number was positive except in 1994 while r_p remained positive throughout. The r_e increased from first generation to second generation after which it started reducing until it became negative in the fifth generation. In both male and female lines egg number was consistently highly correlated genotypically, phenotypically and environmentally.

Table 28 and 30 show the heritability estimates for male line and female line, respectively with the associated standard errors. The results indicate that on the average, ASM, egg number, rate of lay and egg mass have medium to low heritability

while egg weight and body weight have medium to high heritability. Low standard errors associated with these values could be indicative of their reliability.

4.7 Variance components

This is a measure of the variation within a particular population. The total variance was partitioned into that contributed by sire and that which cannot be accounted for and thereby treated as being due to general environmental variation. Tables 10 and 17 show the absolute value of the variance components by traits and by year. However, Tables 11 and 18 showed the percent of the total variance component attributable to sire and error.

In the male line the proportion of the total variance contributed by the sire was generally low being less than 10% for all traits except for average egg weight where the values were above 10% in 1992 and 1993. In the female line, the sire component of variance was actually negative and it was set to zero.

4.8 Selection differential

Selection differential is the difference between the average egg number of the population before candidates for selection were removed and average production of those hens that have been selected as candidates for breeding. The higher the selection differential, the higher is the expected response to selection. Table 33 showed the selection differential, standard deviation and selection intensity. Selection differential of

6.80 and 5.67 for male and female lines, respectively were obtained in 1995 because of an outbreak of new castle disease which killed many of the hens being monitored thereby reducing the number of birds from which selection was made. The average of the selection differential over five generations were 11.44 and 11.63 eggs for male and female lines, respectively.

Standard deviation for egg production in both male and female line was between 10.51 and 16.72. The average standard deviation over the five-year period was 14.73 and 14.53 for male and female lines, respectively. Standardized selection differential is calculated by dividing selection differential with corresponding standard deviation. This value is an estimate of the amount of selection pressure applied. The values were low for 1995 in both male and female lines being 0.46 and 0.42, respectively. The year 1995 was the generation when the flocks under monitoring were drastically reduced as a result of New Castle disease outbreak. On the whole, the average standardized selection differential were 0.78 and 0.80 for male line and female line, respectively.

4.9 Response of egg number (primary trait) to selection

There was little or no response (genotypically or phenotypically) to selection in the male line as shown in Tables 5 and 34 and figure 1. The phenotypic response was

only 0.41 per generation while the genotypic response was negative but not significantly different from zero. The female line population showed a much higher positive response to selection. The phenotypic response was close to 1.7 eggs per generation while the genotypic response was 3.1 eggs per generation (Table 34). This value of the actual response could be compared with predicted or expected response as can be observed in Table 35.

4.10 Correlated Responses

Table 36 and figure 2 showed the expected response to selection in age at sexual maturity as a result direct selection on increase in egg production to 280 days. There was a decrease of about 2 days per generation in age at sexual maturity. Figures 3 and 4 showed the expected response in egg weight and body weight as a result of selection carried out on egg number to 280 days. The expected improvement in egg weight was higher than zero in both lines (also shown in table 33 and figure 3). Body weight was also expected to increase in both lines, the expected gains per generation being 8.23 and 16.61 in both male line and female line, respectively (figure 4). The rate of lay was expected to improve by 2% and 1% for male and female lines, respectively. The expected increase in egg mass per generation was calculated to be 109 and 102 g, respectively for male and female lines.

CHAPTER 5

DISCUSSION

5.0 Effective Population and Inbreeding

The effective number of parents in each generation which averaged about 174 caused an average inbreeding of about 0.5% per generation. The limited population size undoubtedly is major cause of inbreeding depression in performance of this population. Nordskorg et al. (1974) reported an inbreeding coefficient of 0.13 on the average over 7 generation of selection, which is higher than the value reported in the present study. Their effective number however, was considerably lower than those obtained in the population being considered in this study. The effective number in this the population under consideration was therefore considered to be large enough to ensure that rate of inbreeding is reduced to the barest minimum.

Burrow (1993) stated that in the absence of inbreeding, selection is an effective tool in the improvement of most traits of economic importance to livestock breeder. However, it is possible that in closed population, inbreeding depression may overwhelm the positive response from selection resulting in a net loss or a zero gain in performance. The higher the effective population size, the lower the expected inbreeding depression. Studies conducted in beef cattle (McNeil et al.,

1992), in dairy cattle (Ahmad et al., 1974) and in sheep (Erasmus et al., 1991) have concluded that inbreeding has no appreciable effect on responses to selection. In fact, Burrow (1993) concluded that under mild levels and rates of inbreeding, selection is an effective tool in improving performance in heritable traits.

5.1 Selection Response

Selection was effective in improving the egg number in the female line but not in the male line. There was an increase of 1.67 and 0.19 egg per year in both female and male line, respectively. These values are similar to the one reported by Gowe et al. (1959) which was 1.26 eggs per generation. The values of response to selection in this study are also similar in magnitude to those reported by Johari et al. (1989), Gowe and Fairful (1986), Poggenpoel (1986) and Lie (1988). However, when the mean of the selected line was adjusted by subtracting the mean of the appropriate control within a generation, the resulting genetic response was high and significant (P>0.05) in the female line but not in the male line. Low actual egg number was as a result of the delay in sexual maturity especially during the later years of the selection experiment due to unfavourable economic circumstances. Another factor that may have contributed to the variable response achieved from generation to generation may also be due to varying season of hatching across generation.

The selection response in egg number to a fixed age of 40 weeks is a function of rate of lay and age at first egg. However since the age at first egg was

mostly delayed due to an unfavourable economic condition the negative correlation expected with age at first egg contributed negatively to genetic gain in egg number to 280 days while rate of lay was the major positive contributor. It should be noted that the genetic response in the male line is very close to zero.

From the population parameter estimates, the expected increases in egg number per generation were calculated. The actual genetic gain in the female line was far higher than predicted. The opposite was the case in the male line. It could be clearly seen that the realized genetic gain in both lines is different from predicted. Dickerson (1955, 1961, 1963) discussed the issues of variable response to continued selection for egg production and reached the following conclusion.

a. Genetic 'slippage' was due to fluctuating yearly environmental trend
b. Negative genetic correlations were between components of performance
c. Random loss of useful genes was by inbreeding

Genetic slippage according to Dickerson was as a result of selection being mainly directed towards non additive genetic effects or over dominance which dissipate in the next generation. However slippage was not a problem in this work as selection was directed towards a single trait of egg number to 280 days. Inbreeding may possibly have reduced the actual genetic gains but it is expected that this would be offset by increase in selection efficiency using Osborne's index selection over mass selection.

Nordskog et. al., (1974) suggested other causes of ineffectiveness of selection in the present study which include the following:

1. Inadequacy of control population
2. High experimental error
3. Ineffective selection criterion

Inadequate control - The control that was used to correct for environmental trend was derived from a population that has been selected.

The lack of response observed in the male line population selected over five generations is not unusual. Nordskog et. al., (1974) reported a non statistically detectable response in egg production in two breeds of chicken selected for increase in rate of egg production. They found no appreciable response in their White Leghorn selected for part year rate of lay until the 8th generation.

In both male and female line populations, there was positive regression of egg number over five generation. These values represented the phenotypic response of egg number to four generation of selection. After correction for environmental effect by using random bred control population, the regression became negative for the male line while the magnitude of the regression coefficient was increased in the female line. The value of 3.1 eggs reported for the female line

population in this study was higher than those reported by Johari et. al., (1989) and Lie (1988) for White Leghorn population. Liljedahl et. al., (1979) however reported higher response of 4.4 - 6.2 eggs per generation in a selection experiment covering a similar period.

The positive response in the female line population could be attributable to both reduced age at sexual maturity and improved rate of lay. This could be supported by the findings of Liljedahl and Weyde (1980) who reported that contribution at sexual maturity to response to selection lies between 50 and 80% over 4 generations of selection.

5.2 Correlated Responses

The actual responses in age at first egg in the male line and female line were -0.21 and -3.93 days, respectively. This can be compared to the expectation of -2.68 and -2.36 days, respectively. These values are as expected because age at first egg and egg numbers to 280 days are highly negatively correlated. The genes that are responsible for increase in egg production are likely to cause a reduction in age at first egg. Therefore as the frequency of genes responsible for improved egg production is increased, there is corresponding increase in those that cause reduction in age at first egg. The value of -3.93 days per generation obtained in this study is similar to that reported by Brah and Dev (1987) in four populations of chickens. It could be concluded that the reduction in the age at

sexual maturity per generation improved the number of eggs produced to fixed age by increasing the number of days available per chicken to lay.

Egg weight was negatively correlated with the egg number to 280 days in both male and female lines. The magnitude of these values was higher in the female line than in the male line, being -0.64 and -1.21g per generation, respectively. These values were higher than those reported by Kolstad (1980). The reduction in egg weight as the egg number increased per generation may be expected in view of the negative genetic correlation between egg number and egg weight. The explanation for this could be that the same genes responsible for improving egg number caused reduction in egg weight.

The regression of body weight on generation number was negative in both populations when the means were not corrected for environmental effect through the appropriate control population. However when the means were deviated from the appropriate control, there was an increase of 34 g per generation in male line and a decrease of 9.06 g in the female line. The response in body weight over five generations was mostly as a result of environmental changes. Kolstad (1980) reported gain of 11.8g per year in body weight at 50 weeks which was not statistically significant, and which was similar to what was obtained in this study. Egg mass, which is taken as the product of average matured egg weight and egg number showed a negative response to selection in the male line. Whereas the phenotypic response was high and positive in the female line, the genotypic

response was very low and not significantly different from zero.

Rate of lay exhibited a positive trend over years, which is close to 2% in both male and female line populations. The values obtained were higher than those reported by Brah et. al., 1986.

Selection seems to be effective in improving egg production of the female line population. In the male line population it is too early to determine whether selection will cause an improvement in egg production. The overall selection response for egg number in female line was similar in magnitude to those reported by Gowe (1977) who reported hen housed egg production of 1.4 - 1.8 eggs per generation (year) over 17 - 18 years of selection. The result of the male line population in this study is similar to that reported by Nordskog et. al., (1974) who found no appreciable response in their White Leghorn line selected for part record rate of lay after the 8th of altogether 11 generations of selection. Poggenpoel and Erasmus (1978) reported a response of 3.3eggs per generation over 17 generations of selection.

Most of the results obtained in this study did not conform to predicted values as shown in Table 35 probably due to variableness in environmental conditions over the years of the study. This was due to the economic situation that rendered it almost an impossibility to provide uniform environment across the years. Another cause of this variability was probably due to the fact that season of hatching varied from year to year. Hence there are some years when the part year production period fell within the heat period while in other years it fell within the cool harmattan

period fall within the heat period while in other years it fell within the cool harmattan period. Hence environmental effect on egg production varied from one year to another. If the environmental effect in terms of season of hatching had been kept constant, one would expect a positive effect of sub -optimal feeding as practiced on the breeding to cause a positive response in egg production. This type of feeding environment would have allowed the genetic variation to be clearly expressed.

Another cause of lack of response in the male line and such a small response in the female line may be the attack of Newcastle disease that caused high mortality and reduction in egg production during the fifth generation of this study.

In the female line, the gain in egg number is a joint effect of a decrease in age at first egg and increase in percent egg production. In the present study one could conclude that the gain in egg number up to a certain age was determined more by laying intensity and consequently less by age at first egg. Therefore, in accordance with Bohren (1970) selection pressure should be placed on percent egg production measured from first egg to a certain date rather than on egg number to a certain date. This is because the hens that start laying late but with high persistency of egg production will have better chance of being selected as parents of the next generation.

5.3 Genetic Parameter

There was a considerable variation of r_g^2 and r_p^2 between the various generation for all traits considered. On the average sire percentage of total variance is smaller than the dam component for age at sexual maturity in the male line whereas the opposite was the case in the female line. When dam component of variance is higher than the sire component there is said to be maternal effect. However when the sire component of variance is higher sex linkage is assumed to influence the trait in question. It should be noted that more than 60% of the total variances in all traits across years could not be attributable to either sire or dam effects. This was similar to the value reported by VanVleck *et al.* (1963). They also reported maternal effect of 6 - 7%, which is considerably higher than what was estimated for the male line.

5.4 Heritability estimate

The heritability estimate for egg number ranged from 0.05 to 0.35 in the female line and 0.10 to 0.34 in the male line. The pooled estimates from the sire components of variance were 0.13 $\pm$ 0.07 and 0.18 $\pm$ 0.08. This is an indication that sex-linkage effects rather than common maternal environment are major sources of variation. Barua (1983) and Mohapatra and Ahuja (1971) had earlier obtained lower heritability from dam components of variance than sire components.

Osborne (1953) was of the view that when the h^2 from dam component of variance is lower than sire component then sex linkage effect can be assumed. High heritability estimates obtained in this study for egg number is high enough to justify putting considerably more emphasis on individual record. An increase in genetic progress could be expected from the greater selection intensity possible. The h^2 for female line population was similar in magnitude to that obtained by Sorensen et. al., (1980) and Kinney (1969).

The pooled h^2 estimates for age at sexual maturity, body weight at 40 weeks, egg weight at maturity, rate of lay and egg mass were lower than those of Kolstad (1980) Kinney (1969) and Sorensen et al. (1980), Atkare and Khan (1988) and Krishna and Chaudhary (1986). The lower value of h^2 estimates obtained in this study was probably due to large environmental component of variance, which increased the denominator thereby, reducing, generally, the resulting h^2 estimates.

Genetic correlation between age at sexual maturity and egg number was strongly negative. The pooled estimates over 5 generations were -0.86±0.21 and 0.68±0.18 for male and female lines, respectively. These values were similar to their respective base population values.

As expected the correlation between number of eggs up to 280 days and rate of lay as % egg production to age 280 days was 1.00±0.05 and 0.85±0.06 for

male and female lines, respectively. As observed by Kolstad (1980) who obtained a similar result, to some degree, these are two measurements of the same characteristics.

The pooled genetic correlation between egg number and egg weight was small and not significantly different from zero. This is an indication that in the two populations under selection, an increase in the number of eggs does not depress the egg weight. However, another factor that may be responsible for non significant correlation between egg number and egg weight was the individual culling level applied against egg weight that is too small or too big.

Egg mass was highly correlated with egg number being 0.98 and 0.99 for female line and male line, respectively. The r_g was high because the egg mass is mainly determined by egg number and to a lesser degree by egg weight. The value obtained in this study is slightly higher than that reported by Kolstad (1980).

The pooled estimates of genetic correlation over 5 years of body weight with egg number were 0.19 and 0.01, respectively. However the estimates varied from generation to generation and depended on whether dam or sire components of variance were used.

The main cause of the variation may not be unconnected with large increase

in the environmental variation in terms of feed and water supply, which became very erratic during the later years of the selection experiment.

Sire of hen were more accurately identified than the dam as chicks can cross from one compartment to another within a hatching tray belonging to one sire. The effect of such crossing is that a number of chicks are wrongly ascribed to a dam different from her true mother. However, it is almost impossible for a chick to cross from one hatching tray to another one as the hatching trays were covered and stacked one upon another. Hence sires of chicks were mostly accurately identified. This in turn has led to an improvement in estimation of the genetic parameter using sire component.

5.5 Multilocational performance of the commercial layers

The average hen-day and hen house egg production were 278 and 290 eggs, respectively and the ages at first egg, 50 % production and peak production were 136, 168 and 189 days, respectively across all the major ecological zones of Nigeria where the commercial products of the breeding experiment were used. This result is a little lower than those earlier reported by Abubakar et al. (1995). However the results obtained are an indication that selection for improved egg number in the parent lines has resulted in appreciable improvement in the performance of the terminal cross of the two parent lines.

CHAPTER 6

CONCLUSION

From these studies, it appears that environmental variation as measured by the randombred control population varied from year to year. This has affected the magnitude of the genetic parameter, which varied accordingly from generation to generation. Since genetic response is measured by deviating the average performance of the control from the selected line within a generation, the large environmental variation was also reflected in the realized response to selection in both strains of chickens.

Another factor that may cause the observed variation in performance may be differences in the periods of hatching within years across generations. In some years, hatching was carried out during the harmattan period while the part period production of the resulting hens fell within the heat period of March to June while in other years, chicks were hatched during the heat period while production period fell within the cold harmattan period. Effort should therefore be made to synchronize hatching for the selection experiment such that across generations, chicks will be produced about the same time of the year.

Response to selection could be improved by improving the accuracy of selection. This can be achieved by ensuring that adequate environment is provided for the chickens across the years. These mean that there should be adequate water supply, regular feeding all of which should be backed up with good health care.

There was a better response in the female line than in the male in the primary trait of egg production to 280 days. In the production of the commercial day old chicks, the strain that is used for the production of fertile eggs is the female line while the cocks of the male line were kept to mate with them. It is therefore desirable that faster response be made within the female line population. This was indeed what was obtained in the present work.

The genotypic response in the age at sexual maturity, which is known to be highly negatively correlated with egg production to a fixed age, in this case production to 280days, was positive. This means that over the five years of selection, there was linear increase in the age at first egg. This was a direct consequence of regression in the economy of Nigeria, which in turn affected the availability of fund for the project.

A large proportion of the improvement in egg production to 280 days was as a result of improvement in production, which was measured by rate of lay. Since

the production of a chicken was evaluated up to a fixed age of 280 days, a hen may start laying late but after it begins to lay, the rate of laying may be very high and some times higher than some hens that started laying quite early. This was the case with the female line population. Under the present situation selecting for rate of laying to 280days may improve significantly egg production in the present populations being studied. It is therefore recommended that the criteria for selection be changed to rate of lay to 280days.

With the multilocational testing of the commercial layer resulting from the selection experiment, one could conclude that the development of the commercial layer strain has reached an advance state. It has been shown that the adaptability of the commercial layer strain to various Nigerian environments is very high. Continuous selection coupled with concurrent multi-locational testing, it is hoped, will improve the performance of the commercial layer strain beyond the present level.

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