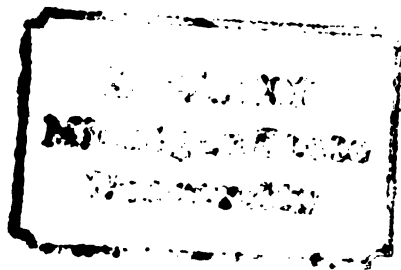This is to certify that the

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GENETIC IMPROVEMENT OF EGG PRODUCTION
IN RING NECKED PHEASANT
(PHESIANUS COLCHICUS)

presented by

Fowzy Abd Fathy

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GENETIC IMPROVEMENT OF EGG PRODUCTION
IN RING NECKED PHEASANT
(PHESIANUS COLCHICUS)

By

Fowzy Abd Fathy

A THESIS

Submitted to
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ABSTRACT

GENETIC IMPROVEMENT OF EGG PRODUCTION
IN RING NECKED PHEASANT
(PHASIANUS COLCHICUS)

By

Fowzy Abd Fathy

The study involved a population that had been selected for egg production. The average improvement per year in egg production was approximately two eggs. The realized heritability for egg production was .22.

Using variance component analysis, haritability estimate for egg production from sires, dams, and dams plus sires combined were $.03 \pm .15$, $.41 \pm .22$, and $26 \pm .07$, respectively, for fertility the estimates were $.12 \pm .28$, $.89 \pm .41$, and $.38 \pm .11$, respectively, for hatchability they were $.19 \pm .17$, $.54 \pm .22$, $.37 \pm .1$, respectively, for livability they were $.97 \pm .11$, $.02 \pm .21$, and $.02 \pm .03$, respectively.

Using regression, traits heritability estimates were $.38 \pm .38$, $.22 \pm 1.12$, $.32 \pm .13$, and $.05 \pm .13$ respectively.

Phenotypic and genetic ocrrelations between egg production and the other traits were small.

ACKNOWLEDGEMENTS

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INTRODUCTION

A selection study for egg production was started at Michigan State University in cooperation with Department of Natural Resources, State of Michigan through the Department of Animal Science.

In order to reduce the cost of raising ring necked pheasants and to meet the need of game pheasant hunters in Michigan, a project was started to improve egg production. The tools which can be used to improve quantitative parameters in birds are principles of applied population genetics; improved nutritional programs and controlling other environmental effects. One of the effective ways to improve the different quantitative traits in poultry, and ring necked pheasant specifically, is to utilize the genetic variation in the pouplation. A knowledge of the size of the heritability of traits is essential in developing breeding programs to utilize genetic variation.

Studying the correlations between different quantitative traits is an effective means to improve and evaluate the production. Egg production can be affected by other traits such as fertility, hatchability, and livability. Hence, the correlation of these traits with egg production can give additional knowledge of how production can be changed.

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REVIEW OF LITERATURE

The genotypic parameters can not be estimated directly in quantitative characters, but must be estimated from phenotypes. The heritability can be defined as a ratio of two variances, the additive genetic variance is the numerator and the phenotypic variance is the denominator which includes individual environmental effects and all genetic effects. Heritability of a trait measures the expected improvement in a population for each unit, the selected parents are above flock average. Heritability of a trait determines the fraction of the selection differential (average performance of parents selected for the trait, flock average) which will be expressed as an improvement in the offspring generation compared to the unselected parent generation (Lush, 1949).

Heritability Estimation

How much related individuals have similarity in genotype is considered the basis for all methods for estimating the heritability. The correlation between the parents and offspring in a large random population can be used to estimate heritability. However, selection of parent would bias estimates based on correlations. On the other hand, even in the parents we selected, regression of unselected offspring on parent will give unbiased estimates (Lush, 1949).

The widely used term regression expresses how much a dependable random variable can be expected to change per unit change of an independent variable.

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The parameters of the model of regular methods of linear regression are supposed to be linear, but these do not have to be a linear relationship between x and y ordinates.

The simple linear statistical model may be written:

$$y = \mu + b \, (x - \bar{x}) + E$$

where μ represents the overall mean of distribution of the variable y. $\bar{x}$ is the mean of the independent (fixed) variable, E represents the random error, and b represents the average change in the independent variable (Gill, 1978). To derive estimates of the linear regression, the least square procedure is used. This procedure gives estimates with the smallest variance and they are unbiased. The estimators will be identical in both the least square theory and maximum liklihood theory if the random errors are independent and normally distributed.

To obtain heritability estimates from regression coefficients, the coefficients are set equal to their expected genetic component.

The heritability estimate by half-sib analysis is a function equal to four times the variance component for sires, which contains additive variance plus a bit of the non-additive variance, divided by sire component variance plus the within sire component (Lush, 1949).

The heritability estimate by full-sibs analysis of variance is similar to the half-sib method except the sire and dam components are an included variance in both the denominator and numerator. The covariance of the full-sibs will equal the variance of the family or sire and dam variance component, while the covariance between the half-sibs is the sire variance components ($\sigma^2 s$). The full-sibs methods of analysis

would be biased by including one-fourth of the dominance variance and a fraction of the epistatic variance (in the numerator).

The variance component for dams will be a function of a covariance of full-sibs minus covariance of half-sibs (Cuningham, 1969).

Using these techniques for heritability estimate, three points should be taken into consideration. These points are material availability, and existence of environmental correlation between closely related individuals and pecularities of mating in the system.

In long term selection experiments an unselected control and/or a group selected in the opposite direction at the same time is needed to get information of the best estimate of heritabilities (Lush, 1949).

Variance is a measurement tool by which the variation can be estimated in a population. It is the average squared deviation of the individuals from the population average. The total variance can be divided into that due to environmental (σ^2_E), and variance due to difference in heredity (σ^2_H). The last one can be divided into the additive, dominance and epistastic variance. In a non-selected sample of data in which we have sires, dams within sires and progency with dams, estimations of heritability can be made from the estimations of the components of variance. King and Henderson (1954a and 1954b) and many other authors used the hierarchal or nested classification analysis of variance model for estimation of the variance components which are used to estimate heritability. The statistical model is:

$$y_{ijk} = \mu + g_i + s_{ij} + e_{ijk}$$

where y_{ijk} represents the records of the kth progeny of the jth dam mated to the ith sire, μ represents the common mean of distribution, g_i represents the effect of jth dam mated to i^{th} sire, and e_{ijk} represents a sampling error.

Kempthorne and Tandon (1953) reported using three methods of computing the regression of offspring on dam where the number of offspring per parent is not constant. The computed estimation of heritability by repeating the dams records with each daughters records, and by regressing the average of all daughters of a dam on the dam records. A third estimation of heritability was computed by using a weighing system based on a number of offspring in a family average which would give an unbiased estimate of the regression with minimum sampling error. The difference among the heritability estimates obtained using the three procedures were small.

Blow et al. (1958) reported that when the dams and sires are selected the regression of offspring on dams still gives an unbiased estimate of heritability.

Nordskog et al. (1959) reported that in a population which has genetic environmental interaction, the use of the component of variances from either a half-sib or full-sib analysis gives a biased estimate of heritability. The estimates are not biased when the method of intra-class regression is used. They also reported that heritability of egg production and body weight, when estimated by intra-class correlation between sibs, by variance components estimate, or by intra-sire regression of daughter on dam weighted by number of daughters produced no differences in heritability estimates despite high sampling error between light and heavy breeds of chickens.

Becker (1966) gave an excellent example of how to calculate estimates

of heritability and genetic correlations. Thomas et al. (1959) established
that the additive genetic variance resulting from the dam component of
variance tends to be higher than the sire variance component and that
additive genetic variance contributed to the male progeny.

Genetic Effects on Traits in Poultry

Egg Production

Wyatt (1955) reported that in chickens the heritability estimates
for egg production derived from full-sibs correlation and from regression
of daughter on dams for the period from December First to May 31 were
0.00 $\pm$ .11, and .51, respectively.

Shakly et al. (1953) established that the heritability of egg
production from full-sibs and paternal half-sibs correlation and regres-
sion of the offspring on dams was approximately .40 for yearly production
in turkeys.

McCartney (1962) reported a heritability estimate of .49 for egg
production in a random bred population of turkeys using the variance
component analysis based on twice the full sister correlation. This is
the best estimate of heritability even though it contains non-additive
genetic variance.

King and Henderson (1954b) reported that in a leg horn population
the estimates of heritability of survivor's egg production to January 1st.,
March 1st, June 1st, and annual were .48, .46, .39, and .31, respectively,
by applying the variance component analysis procedure.

Jerome et al. (1956), using the variance component estimates for sires,
dams, and sires plus dam, obtained heritability estimates for the total
egg production in 365 days after date of first egg of .13, .11, and .12,

respectively. Heritability could have been low because a considerable proportion of the favorable genes for the production for the full laying year have become fixed due to long term selection.

Nordskog et al. (1959) reported that the heritability estimates and standard errors obtained from the variance components as best linear un-biased estimate for the combined breeds of light and heavy breeds in chickens were .6 $\pm$ .063, .57 $\pm$ .065, .23 $\pm$ .062, respectively, for egg weight, March body weight, and winter egg production.

Saddeh et al. (1968) using hierarchal analysis of variance to estimate sire components obtained pooled heritability estimates and standard errors of .10 $\pm$ .16, and .12 $\pm$ .15 for rate of lay to 260 and 500 days of age in chickens, respectively.

Jerome et al. (1956) reported an estimate of genetic correlation between four months egg production of survivor's and fall egg weight of -.24 using sire and dam covariance components.

Jaap et al. (1962) recorded the heritability estimates from the sire component for egg production over a 69 day period from the 23rd to 46th week in the random bred white gold chicken was .28.

The genetic correlations between eight week body weight, 16 week body weight, and 24 week body weight versus the egg production to 46 week, were .15, .09, and .10, respectively.

By regressing the genetic gain on the accumulative selection differ-intial in turkeys, McCartney et al. (1968) found that the realized heritability estimate and standard error of 84-day egg production obtained in the egg line was .61 $\pm$ .12. The realized genetic correlation estimated between eight week body weight and egg production, 24 week body weight and egg production averaged -.40 $\pm$ .22, and -.14 $\pm$ .10, respectively.

Nestor (1972) using turkeys, reported that the regression of genetic gain on the accumulative selection differential gave an estimate of realized heritability for 84 day egg production of .33 ± .05. The linear regression coefficient of 84 day egg production on years was 1.45 for the egg line (line selected for egg production).

Nordskog et al. (1975) using a ten year multi-selection experiment with white leg horn and Fayoumi chickens found that selection for large egg size lowered efficiency and selection. Selection reduced the genetic variation in some lines of leg horns and Fayoumis.

McCartney et al (1968), using a selection experiment in turkeys, found that five generations of selection for increased egg production resulted in a small decrease in body weight of male offspring. Selection was effective in all lines of turkeys, both the egg and body weight lines. The realized heritability for egg production obtained in the line selected for high egg production (egg line) averaged .61 ± .12.

Inbreeding has a depressing effect on the level of performance for many traits. When the degree of inbreeding is increasing rapidly, the effect of the inbreeding on the performance traits must be included in any analysis of the genetic effects influencing these traits.

Gordon (1957) reported that inbreeding effect anticonize the direction of selection in a flock of poultry specifically selected for egg production which showed a decrease of one egg for every percent increase in the computed inbreeding coefficient.

Egg production was affected more by inbreeding than were body weight or egg weight in Japanese quail (Kulenkamp et al., 1973).

Stephenson et al. (1975) reported that in white leg horn the effects of inbreeding on egg production were linear after the inbreeding coefficient

exceeds 25 percent. The general regression of egg production rate on inbreeding coefficient was to be -.43 ± .04.

Casey and Nordskog (1971) reported that there is no important loss of genes for high egg production when a population is selected exclusively for a trait like body weight or egg production for as many as ten successive generations. They also concluded that for each ten percent increased in inbreeding in the selected lines the rate of egg production declined 5.3 percent.

Fertility

Kondra and Shoffner (1955) reported that using the intrasire regression of offspring on dams to estimate heritability resulted in an estimate of -.14 to 1.98 in turkeys.

Kondra and Shoffner (1955) and Rooney (1957), found that in turkeys the correlation between fertility and body weight is negative.

Studying the effect of body weight upon fertility in broad breasted bronze turkeys, Rooney (1952) reported estimates of heritability of fertility, using variance component methods, that were approximately 11 percent and 16 percent higher for small hens than for medium and large hens, respectively. A correlation of .99 was found between weekly fertility average and corresponding percent of live embryos after seven or eight days of incubation.

McCartney et al. (1968) in a selection experiment found that fertility in turkeys decreased and number of poults per hen increased in the line selected for high number of eggs.

Blow et al. (1951), using the phenotypic correlation between full sisters in turkeys, obtained a heritability estimate for fertility of .80.

Wing (1976), in ring necked pheasants, reported that the fertility percentage averaged for the eight hatches was 41.0, for three hatches was 53.0, for four hatches was 30.5. He attributed the low fertility percent to infertility of the male breeders used in 1975 and the early part of the breeding period in 1973, 1974. On the other hand, fertility percentage in the ring necked pheasant as Carpenter (1980) reported was within the range of 69.56 to 80.64.

Hatchability

McCartney (1962) studied hatchability in turkeys. He reported that heritability of hatchability when the traits is considered as a trait of individual females relatively low; therefore it would be necessary to undertake family selection in improve hatchability.

Carpenter (1980) reported, in pheasants, that hatchability percent was within the range of 65.43 to 75.29 in two successive years.

Wing (1976) established that the average percent of hatchability for eight hatches for 1973 was 67.9, for three hatches for 1974 was 72.0, and for four hatches for 1975 was 69.4 percent in the ring necked pheasant.

Woodard and Morzenti (1975) and Woodard (1971) reported that hatchability in game birds was 67.1 percent for unturned eggs, and 60.4 percent for turned pheasant eggs held up to seven days. In general, the hatchability without considering the turning ranged from 40 to 60 percent.

Wing (1976) reported that in the pheasants with which he worked hatchability for 1973 for eight hatches averaged 67.0 percent. For the last three hatches (7,8,9) for 1974, it averaged 72.0 percent; and for all eggs that year it was 38.6 percent. For the first four hatches in 1975 the average was 69.4 percent.

MATERIALS AND METHODS

Management

The study of egg production potentials of ring necked pheasants started in the 1970's by Sheppard and Flegal. These different strains of pheasants composed the base population. The number one strain came from the Mason Game Farm, Mason, Michigan. The other two were obtained from the Bauer Game Farm, Lapeer, Michigan.

The general management procedure for handling the birds each year will be described in the following paragraphs. It was the same for each of the years included in the research from 1978 to 1981.

The one day old chicks were wing-banded according to their families (sires and dams), and they were taken to the Poultry Science Research and Teaching Center (p.S.R.T.C.). The house in which the birds were raised contained 32 separated pens, each 3.05 x 4.88 meters. Each pen had a thin layer of wood shavings of 5-centimeters thickness on the floor. Birds of each hatch were placed in pens supplied with continuous light for the first three days of age to enable the baby chicks to locate the waterers and feeders. Birds of each hatch were brooded in separated pens. Circular chick guards were placed around the baby chicks for the first five days to keep the birds confined under three infra-red heat bulbs. The bulbs were hung about 75- centimeters above the floor. The bulbs were raised as the birds got older. Each week, one infra-red bulb was removed. Heat was also supplied by a brooder canopy hung 152 centimeters above the pen floor, alternatively with pens.

A pheasant starter ration in crumbled form (Appendix Table C) was provided ad Libitum. When the birds were six weeks of age, feed was changed to grower ration (Appendix Table D) supplied ad Libitum. Maintenance ration was fed the birds at 12 weeks of age (Appendix Table A).

Water was provided in two jars per pen plus mechanical waterers. After four weeks only the cup-like mechanical waterers were used. Other waterers were removed.

Daily inspection of the bird's condition, removing of dead birds, cleaning waterers and other management chores were performed regularly.

Sex was determined when difference in plumage colaration in the males and females could be used as a means of sexing at six to eight weeks of age.

Breeders to be used to produce the next generation were selected primarily on the basis of their dam's egg production. Breeder birds for 1978, 1980 were selected as the upper 46.9 percent, 16.21 percent and 24.22 percent, respectively.

Then selected breeders were transferred to individual suspended cages. In the cage room, light was set on 24 hours a day for the first two day periods to help the bird locate the water nipples and feeders.

The lighting regimes were designed to expose the birds to eight hours light and 16 hours dark (8L:16D) until birds were to be stimulated to come into production. In the first week of January the light was set to provide birds with 14 hours light and ten hours dark (10D:14L), to stimulate semen and egg production. At the time of lighting, the bird's ration was switched from pheasant grower (Appendix D) to breeder ration (Appendix B).

Two weeks after lighting, egg production reached about 10 percent, and semen production was initiated. Breeding of hens began when egg

production was about 50 percent; five to six weeks after the lights were turned on.

Four to six hatches of pedigree chicks were obtained each year. The females were mated by artificial insemination. Two people performed the semen collection and insemination.

Approximately .025 milliliter of undiluted semen was injected into the vagina of the assigned females by using a sterile labeled plastic micropipette tube for each female used.

After the hens had been bred, they were put into cages. A large number of hens were bred in order to produce a large selection differerential when the young birds were selected on their dam's egg production records.

Eggs were collected daily and labeled by writing the hen number on the egg. The eggs were stored at about 15.6 $^{\circ}$C until time of incubation. The eggs were held for not longer than a week and incubated as a group. Four pedigree hatches were produced per generation (year).

The incubators used were James Way 252 single stage. The temperature maintained during the incubating period (three weeks) was 37.5° C with 60 percent relative humidity. During the hatching period (last two-four days), the temperature was 36.9° C with 70 percent relative humidity. The hatched chicks were left one day in the hatcher for the purpose of drying off.

Eggs were candled at seven days incubation in order to determine percent of fertility. The eggs which were candled out were broken to be examined macroscopically, to determine if they contained an early dead embryo or were infertile.

Individual egg production of the ring-necked pheasants surviving for 120 days egg production in 1978, 1979, 1980 and 1981 were included in the

study. The size of the ring necked pheasant population for the above years was 216, 259, 227 and 186, respectively.

Individual egg production was the total number of eggs laid by a hen in 120 days after the flock was judged to be in production. Inadvertently, in 1981 all hens were disposed of after 107 days of production. To make the 1981 egg production on a 120 day basis, the actual number was multiplied by 120/107. Factors relating to offspring production were calculated on the following basis:

$$\% \text{ fertility} \quad = \quad \frac{\text{no. egg fertile}}{\text{no. set}} \times 100$$

$$\% \text{ hatchability} \quad = \quad \frac{\text{no. banded}}{\text{no. fertile}} \times 100$$

$$\% \text{ livability} \quad = \quad \frac{\text{no. birds survived until time of selection}}{\text{no. banded}} \times 100$$

Each of these factors has a denominator. If a denominator was missing for a given hen, the value for the factor for that hen was considered as a missing value.

Estimates are biased upward to the extend that restricting eggs saved to only females which had about 10 live offspring at breeding time was a selection force on fertility, hatchability, and livability. Since almost all the selection was on the basis of egg production, the amount of this bias should be small.

Statistical Analysis

For the purpose of heritability estimates and relationship between traits, three methods of statistical analysis were used using Cyber 750

computer at Michigan State University Computer Center.

Response to Selection

The first technique applied to obtain heritability estimates was based on selection differential and the estimated improvement. The realized heritability for 120 days for egg production was calculated according to McCartney et al. (1968) as the yearly response to selection divided by the average selection differential.

Variance Component Estimate

The second method used to estimate the heritability for the traits was the variance component procedure. They were derived from the hierarchal nested model as listed in King and Henderson (1954b). The statistical model used was as:

$$Y_{ijkl} = \mu + y_i + s_{ij} + d_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = a performance record for the Lth progeny from kth dams mated to jth sires with ith years.

μ = overall mean for all population.

y_i = fixed year effect.

s_{ij} = jth sire (variable effect) in the ith years.

d_{ijk} = effect of kth dams mated to jth sires in ith years

e_{ijkl} = uncontrollable experimental error

This model can be related to a genetic model. The genetic model of the nested design contains the variances component to sires, σ^2_s. The variance component for sires contains one fourth of the additive genetic variance, zero dominance variance and a small amount of the epistatic variance. Another variance component in the nested model is for dams, σ^2_d. The dam variance component is equal to the covariance between the full sibs minus the covariance between the half-sibs which contain one-fourth of the additive genetic variance and one-fourth of the dominance variance and some of the epistatic variance. The variance of the progeny within the dams, σ^2_w, contains the remainder of the genetic variance and the enviromental variance or the total variance minus the full-sibs covariance which contains one half of the additive genetic variance and three fourths of the dominance variance plus the remainder of the epistatic variance (Becker, 1966).

The mean squares estimates of variance from our analysis were applied according to Table 1 to solve for the estimated sire variance component, $\hat{\sigma}^2_s$, and the estimated progeny within dams (full-sibs) variance component, $\hat{\sigma}^2_w$, according to Becker (1966).

Table 1. Analysis of Variance and Expected Mean Squares.

Source	d.f	SS	MS	E(MS)
Years	a-1	A-C	-	-
Bet. sires within years	s-a	B-A	SS_s/s-a	$\sigma^2_W + k_2\sigma^2_D + k_3\sigma^2_S$
Bet dams within sires	d-s	D-B	SS_D/d-s	$\sigma^2_W + k_1\sigma^2_D$
Bet. progeny within dams	n-d	I-D	SS_W/n-d	σ^2_W

The values used to calculate SS are:

$$\frac{(Y....)^2}{N} = \text{The correction factor for the mean} = C$$

$$\Sigma\frac{(Y_{i...})^2}{n_{i..}} = \text{The adjusted SS for the years} = A$$

$$\Sigma\frac{(Y_{ij..})^2}{n_{ij.}} = \text{The unadjusted SS for the sires} = B$$

$$\Sigma\frac{(Y_{ijkl})^2}{n_{ijk}} = \text{The unadjusted SS for the dams} = D$$

$$\Sigma(Y_{ijkl})^2 = \text{The unadjusted SS for the individual} = I$$

d = number of dams.

s = number of sires.

a = number of years.

N = n... = number of individual

$n_{i..}$ = number of offspring for ith year.

nij. = number of sffspring for the jth sires in the ith years.

nijk = number of offspring out of the kth dam mated to jth sire in the ith years.

Estimating the variance component:

$$\hat{\sigma}^2_W = \text{The variance of progeny within dams} = MS_W$$

$$\hat{\sigma}^2_D = \frac{MS_D - MS_W}{k_1}$$

$$\hat{\sigma}^2_S = MS_S - \frac{(MS_W + k_2\sigma^2_D)}{k_3}$$

where:

k_i = coefficient for unequal number of progeny per sire calculated as Becker (1966).

$$k_1 = \frac{N - \Sigma_{ij} \frac{\Sigma_k n^2_{ijk}}{n_{ij.}}}{d-s}$$

$$k_2 = \frac{\Sigma_{ij} \frac{\Sigma_k n^2_{ijk}}{n_{ij.}} - \frac{\Sigma_{ijk} n^2_{ijk}}{N}}{s-a}$$

$$k_3 = \frac{N - \Sigma_i \frac{\Sigma_j n^2_{ij.}}{n_{i..}}}{s-a}$$

The heritability estimates based on sires variance component, h^2_S, dams variance component, h^2_D, dams and sires variance components combined, h^2_{D+S}, are:

$$h^2_S = \frac{4\hat{\sigma}^2_S}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

$$h^2_D = \frac{4\hat{\sigma}^2_D}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

$$h^2_{D+S} = \frac{2(\hat{\sigma}^2_S + \hat{\sigma}^2_D)}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

The approximate value for the standard errors were calculated according to Becker (1966).

The correlation between traits has also been estimated as suggested by Becker (1966). The phenotypic correlation $r_{P_x P_y}$ between traits is estimated as the total sums of the estimated covariances of the dam, sire, and progeny within dam divided by the square root of the summed estimated variance component of the sires, dams, progeny within dams for the first trait (x) multiplied by the summed estimated variance components of the sires, dams, progeny with dams for the second trait (y).

$$r_{P_x P_y} = \frac{\hat{cov}_S + \hat{cov}_D + \hat{cov}_W}{(\hat{\sigma}^2_{S(x)} + \hat{\sigma}^2_{D(x)} + \hat{\sigma}^2_{W(x)}) * (\hat{\sigma}^2_{S(y)} + \hat{\sigma}^2_{D(y)} + \hat{\sigma}^2_{W(y)})}$$

The genetic correlation was calculated using the estimated covariance of the sires, and the covariance of the dams and the estimated variances of the sires and the estimated variance of the dams for both traits as shown below:

$$r_{G_x G_y} = \frac{\hat{cov}_S + \hat{cov}_D}{(\hat{\sigma}^2_{S(x)} + \hat{\sigma}^2_{D(x)}) * (\hat{\sigma}^2_{S(y)} + \hat{\sigma}^2_{D(y)})}$$

The Genstat package (Alocy et al., 1977) was used to calculate mean square covariance and k's values.

Intrasire Regression

The third method applied to calculate the heritability estimate for traits was the intrasire regression of daughters on the dams according to Lush (1949).

$$\hat{H}_{er.} = 2\, b_{P_0 P_D}$$

where:

$\hat{H}_{er}$ = heritability estimate

$b_{P_0 P_D}$ = the regression of offspring phenotype on the dams phenotype.

The standard errors were again calculated using the procedure presented by Becker (1966).

RESULTS AND DISCUSSION

Egg production for 120 days in ring necked pheasants was measured for four generations from 1978 to 1981. This was a continuation of the primary study conducted by Flegal and Sheppard in the 1970's.

Response to Selection

One of the aims of analysis of these data was to evaluate the progress made in increasing egg production of the ring necked pheasant for the first 120 days of production. Egg production records for 888 birds, over the four generations, were available for this analysis. Breeders to be used to produce the next generation were selected on the basis of their dam's egg production. Selection on dams production whould improve egg production in the flock. Consequently, breeder birds in 1978 were selected as 46 percent. The remainder 43 percent were culled. For 1979 breeders were selected from the top 16 percent. Breeders for 1980 were selected from 24 percent. Offspring records for the birds selected in 1981 were not available at the start of this study. Thus, the selection differential for 1981 was not used in this study.

Table 2 shows a comparison between 120 day egg production means of the selected and selected unselected (all) groups. Selection of breeders on the basis on dam's production was, in most cases, effective in improving egg records in the next generation. For the unselected group (all) the production was almost the same as the next two years except in 1979 where it increased about 10 eggs. This may have been due to improved

Table 2. The yearly means of all hens and those selected to have offspring saved for egg production, fertility %, hatchability %, and livability %.[e]

Year	No. birds	No. egg production[a]		% Fertility[b]		% Hatchability[c]		% Livability[d]	
		All	Selected	All	Selected	All	Selected	All	Selected
1978	216	79.0	93.8	66.1	80.7	65.9	79.2	91.0	84.5
1979	250	88.0	107.2	66.6	78.4	63.3	76.7	93.2	92.0
1980	227	87.7	104.0	79.0	89.1	76.8	83.4	74.7	77.1
1981	186	86.0	106.1	74.0	80.9	71.2	72.2	93.4	95.0
Mean	888	85.8	104.0	71.4	82.3	69.3	77.9	88.0	87.2

[a] Egg production was on 120 day basis. In 1981 the birds were mistakenly shipped at 107 days. Data for 1981 were adjusted to 120 day basis by multipling actual egg number by (120/107).

[b] % fertility = $\dfrac{\text{No. egg fertile}}{\text{No. egg set}} \times 100$

[c] % hatchability = $\dfrac{\text{No. banded}}{\text{No. fertile}} \times 100$

[d] % livability = $\dfrac{\text{No. birds survived until time of selection}}{\text{No. banded}} \times 100$

[e] In any case where the denominators is zero, the observation is considered as a missing value.

management in that year. So the most acceptable explanation of the increase
in the selected group of birds is that it was probably due to the effect
of selection which increased the gene frequency for egg production genes,
except in 1980 where egg production was decreased from the previous year,
1979 by almost two eggs. This change possibly could be attributed to
environmental effects or sampling error. For all years it is assumed
that the overall environmental effect for a given year is a random effect
with no trend over time.

The selection differentials for 120 day period egg production in the
ring necked pheasant for the year 1978, 1979, 1980, were 13.47, 19.72, 21.3
eggs, respectively, with an over all mean of 16.5. The production of the
hens selected in 1981 had not been recorded when this analysis was started.
The selection differential was calculated as the differences between
average of the selected birds records minus the overall mean. The overall
selection differential was computed by taking an average of the selection
differentials of the first three years.

The regression of egg production on years was approximately two
eggs per year which represent the average yearly improvement in 120 day
period egg production as a response to selection.

The realized heritability for egg production was .24. This was a
larger value than that (.065) reported by Wing (1976). He attributed
the small value to the lack of reliability due small population size.

In Leghorn and Fayomi, realized heritability and standard error
were .07 $\pm$ .04 and .03 $\pm$ .14, respectively, as reported by Nordskog et
al. (1975). In egg line turkeys, McCarthey (1968) reported that realized
heritability and standard error computed by regressing the genetic gain
on the accumulative selection differential for an 84 day period was

.61 ± .12 which is higher than that found in our work.

Nestor (1972), in turkeys, reported that the realized heritability and standard error was .33 ± .05 which is also higher than our estimates in the ring necked pheasant.

In our data, the correlated response of fertility and hatchability with egg production were so large that estimates of genetic correlation would be biologically impossible.

Estimates of Genetic Effects from Variance Components

For variance component analysis, the total number of birds for four years was 795. The birds who had no sire record were excluded from the variance component analysis. For the analysis there were approximately 40 dams, and 25 sires per year. There were about four offspring per dam and about eight offspring per sire.

Table 3 shows mean squares for egg production, fertility and the mean cross product of egg production with fertility, hatchability, and livability for the sources years, sires within years, dams within sires and progeny within dams.

Hertability estimates for the traits of egg production, fertility, hatchability, and livability were computed from the sires variance components, dams variance components, and from the dams plus sires combined are shown in Table 4. The estimation of the variance components were obtained by equating the means squares in Table 3 to their expectation as shown in Table 1.

The egg production heritability estimate from the sires variance component is a smaller estimate value (.03 ± .15) than from either the dams variance component estimate (.41 ± .22) or the dams plus sires

Table 4. Heritability estimates using variance components of sires, dams, dams plus sires combined for egg production, fertility, hatchability, livability.

Trait	$\hat{h}_S$ from sires component[a] and standard error	$\hat{h}_D$ from dams component[b] and standard error	$\hat{h}_{D+S}$ sires plus dams[c] combined and standard error
Egg production	.03 ± .15	.41 ± .22	.22 ± .07
Fertility	-.12 ± .28	.89 ± .41	.38 ± .11
Hatchability	.24 ± .17	.54 ± .22	.39 ± .10
Livability	-.07 ± .11	.02 ± .21	-.04 ± .03

where: $\hat{\sigma}^2_S$ = estimate of variance component of sires.

$\hat{\sigma}^2_D$ = estimate of variance component of dams.

$\hat{\sigma}^2_W$ = estimate of variance component of errors.

a
$$\hat{h}_S = \frac{4\hat{\sigma}^2_S}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

b
$$\hat{h}_D = \frac{4\hat{\sigma}^2_D}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

c
$$\hat{h}_{D+S} = \frac{2(\hat{\sigma}^2_S + \hat{\sigma}^2_D)}{\hat{\sigma}^2_S + \hat{\sigma}^2_D + \hat{\sigma}^2_W}$$

Table 3. Mean squares (MS) and mean cross product (MEP) for egg production (E), fertility (F), hatchability (H), and livability (L).[a]

Source	dif	$MS_{(E)}$	$MS_{(F)}$	$MS_{(H)}$	$MS_{(L)}$	$MCP_{(EL)}$	$MCP_{(EH)}$	$MCP_{(EF)}$
Years	3	4141.00	7358.40	6156.10	13415.00	-3485.30	1294.90	2775.40
Sires within years	99	929.19	914.10	867.86	206.16	4.76	119.43	46.70
Dams within sires	78	860.04	988.46	663.33	237.14	- 88.24	214.19	141.91
Progeny within dams	614	582.62	464.30	394.15	231.64	- 39.13	25.87	60.13

[a]The k values, as shown in Table 1 associated with the different mean squares are k_1 = 4.1, k_2 = 4.6, and k_3 = 7.6, respectively.

combined variance component estimate .26 ± .07 value. It is also very small estimate compared to those reported by other authors in chickens and turkeys. Wing (1976), in his thesis, reported that in the ring necked pheasant the pooled heritability estimates for 120 day egg production survivors using the sire's variance components, dam's variance components, and dams plus sires combined variance component estimates were .32, .80, and .56, respectively, which are considered higher estimates than those computed in the present study. He attributed the magnitude of his estimate to the smaller ring necked pheasant population size in his study.

The .03 estimate harmonizes with that of Merrit and Weader (1968) who used variance component analysis in chickens.

Jaap and Goodman (1962) reported that in chickens heritability estimate of egg production by sire variance components analysis was .28, which is higher than reported herein.

Saadeh and Weader (1968) using sire variance component analysis reported that in the chicken egg production heritability estimates and standard errors for 260 and 500 day periods were .10 ± .16, and .20 ± .15, respectively, which are also higher than we concluded for pheasants. In turkeys, the egg production heritability estimate and standard error reported by using the variance component was .23 ± .16 which is also higher than ours.

The estimate base on dam variance component for egg production heritability estimate is .41 ± .22 which was the highest value computed.

The combined dams plus sire variance component estimate was 26. This estimate has a lower standard error than either of the other estimates. Using dams plus sires variance component, McCartney (1962), in turkeys, reported that the heritability estimate was .49 which is also higher than

that calculated in pheasant in this study.

The phenotypic correlation between egg production and fertility, hatchability, and livability are small. They are positive between egg production and both the fertility (.1) and hatchability (.1), but negative for livability (-.1).

The correlations of egg production and fertility, hatchability, and livability are shown in Table 5. The genetic correlation between egg production and fertility was .22 and .07, respectively, on the basis of covariance of the dams, and covariance of the dam plus sires combined. The genetic correlation between egg production and hatchability on the basis of sires, dams and dams plus sires were -1.24, .69 and .36, respectively. The genetic correlations between egg production and livability on the basis of the dams covariance and dams plus sires combined covariance were -1.25, .03, respectively.

The genetic correlation between egg production and fertility, hatchability and livability on the basis of the dams plus sires combined was low, as were the phenotypic correlations. The estimates based on sire or dams component alone were highly variable due to large sampling errors. The phenotypic and genetic correlation estimates for the traits under study were not available in the literature.

Estimates Based on Regression

The heritability estimate and standard error of 120 day egg production from regression of daughters records on dams records is shown in Table 6. The estimate is close to that estimate calculated from dams variance components shown in Table 5, but the standard error in the regression method is larger than that the variance component method.

Table 5. Phenotypic and genetic correlation between egg production and fertility, hatchability, and livability.

	Egg production and fertility			Egg production and hatchability			Egg production and livability		
Phenotypic[a] correlation	.15			.099			-.098		
	sires[c]	dams	combined	sires	dams	combined	sires[c]	dams	combined
Genetic[b] correlation	--	-.22	.07	-1.24	.69	.36	--	-1.25	.03

[a]
$$r_{P_x P_y} = \frac{\hat{cov}._S + \hat{cov}._D + \hat{cov}._W}{\sqrt{\hat{\sigma}^2_{S(x)} + \hat{\sigma}^2_{D(x)} + \hat{\sigma}^2_{W(x)}} * \sqrt{(\hat{\sigma}^2_{S(y)} + \hat{\sigma}^2_{D(y)} + \hat{\sigma}^2_{W(y)})}}$$

[b]
$$r_{G_x G_y} = \frac{\hat{cov}._{S(xy)}}{\sqrt{\hat{\sigma}^2_{S(x)} * \hat{\sigma}^2_{S(y)}}}$$; This is the case for the sire variance component, similar equations are used for dam variance component and the combined variance component.

[c] In cases where the denominator is a negative no estimates were made. In cases where the estimated variance components was negative but the other was positive and larger, an arithmatic mean rather than a geometric mean was used as the denominator.

Table 6. Heritability estimates and standard errors for the different traits from regression of daughter on dams.

Trait	d.f	Heritability	Standard error
Egg production	643	.38	± .38
Fertility	595	.22	± 1.12
Hatchability	582	.32	± .13
Livability	565	.05	± .13

Contrasted to that, it is significantly larger than the heritability estimates from both the sires variance component and the dams plus sires combined variance component and their standard errors were also smaller than those derived from use of the regression technique.

Comparing the heritability estimate from the regression of the daughters on dams with the realized heritability estimate, shows a larger value for the regression procedure. Wing (1976) reported a pooled heritability estimate of .30 in ring necked pheasants which is a lower value found in this study.

Wyatt (1955) in chickens and Shaklee et al. (1952) in turkeys reported heritability estimates of .51 and .40, respectively. So our estimate is close the the turkey heritability estimate and a little lower than the chicken heritability estimate.

Fertility

Table 2 shows the relationship of 120 day egg production and mean fertility percentage in the ring necked pheasant. The group unselected (all) mean is about 10 percent less than the selected group mean. In the years 1980 and 1981 there were significant increases in fertility percent. This may be attributed to the improvement in management. The fertility was calculated as the number of eggs fertile multiplied by a hundred and divided by number of eggs set. The fertility estimate by this analysis is close to the estimate Woodard (1971) stated in game birds.

Carpenter (1980) who worked on ring necked pheasants reported a variation of fertility percent ranging between 44.6 and 74.8 percent. He attributed this variation to environmental effects. Wing (1976) in

ring necked pheasants tabulated average percent fertility for eight
hatches of .41 which was far below the estimate of the present study.
The correlated change of fertility with egg production was so large
that sampling error made any estimates of genetic correlation impossible
(Table 2).

Table 3 gives mean squares and the mean cross product between egg
production and fertility for the years, sires within years, dams within
sires, and progeny within dams. The only positive estimate is of a mean
cross product for the source sires within years. Fertility heritability
estimate and standard error using variance component of sires, dams, and
dams plus sires combined were .12 ± .28, .89 ± .41, and .38 ± .11,
respectively as Table 4 shows. The highest fertility estimate value was
from the dams variance component which had the highest standard error as
well. The estimate with the smallest standard error estimate was the one
from the dam plus sires combined. In general, the combined estimate of
heritability and standard error is considered the most reliable one.
Table 6 shows the fertility heritability estimate and standard error .22
± 1.1 from the regression of daughters on dams.

No fertility heritability estimates were found in the literature.

Hatchability

The hatchability percent of the ring necked pheasant was calculated
on the basis of 120 day egg production.

Table 2 shows the hatchability of the selected group mean was 78.0
percent and unselected (all) group mean was 69.4 percent. There is about
8.6 percent increase for the selected group over the unselected. For
the "all" group, the highest percent (76.8) was in 1980, and the lowest

percent (63.3) was in 1979 (Table 2). The hatchability was calculated as the number of banded chicks times one hundred divided by number of fertile eggs.

The unselected group estimates are close to those Carpenter (1980) reported in the ring necked pheasant. On the contrary, Woodard and Morzenti (1975) reported a hatchability of 63.7 percent for pheasant eggs held no longer than one week prior to beginning of incubation.

The mean squares and the mean cross product of hatchability, and hatchability with egg production for years, sires within years, dams within sires and progeny within dams are shown in Table 3. The hatchability heritability and standard error using the variance component of sires, dams, and dams plus sires were .19 ± .17, .54 ± .22, and .37 ± .1, respectively (Table 4). The dams variance component includes one fourth of the dominant effect and maternal effects which tends to make the estimate from dams component above the true value. The smallest standard error (.1) was derived from dams plus sires combined variance component.

Table 6 shows the hatchability heritability estimate and standard error (.32 ± .13) from the regression of daughters on dams.

No estimate of the hatchability heritability could be found in the literature.

Livability

Table 2 shows, on the bais of 120 days egg production livability percent means for both selected and unselected "all" were almost the same for the groups, the lowest value (74.7 percent) was in 1980, and the highest (93.4 percent) in 1981. The livability was calculated as number of birds alive at time of selection multiplied by one hundred

divided by number of chicks banded at day old.

The mean squares of livability, and the mean cross product of egg production with livability for years, sires within years, dams within sires, and progeny within dams are all shown in Table 3.

Livability heritability estimates using variance component of sires, dams, and dams plus sires were .07 $\pm$ .11, .02 $\pm$ .21 and -.04 $\pm$ .03, respectively (Table 4). Table 6 shows the livability heritability estimates and standard error from regression of daughters on dams. The heritability estimate is very low (.05). The standard error is as large as that for hatchability but both are smaller estimates than either the egg production or fertility standard error estimates.

No estimates were found in the literature concerning livability in poultry.

CONCLUSIONS

Selection of birds to breed..for.the next year was bsed on the dams production. Over the years, birds were selected from dams that were in the top .29 percent with a selection differential of 16.5 eggs. The annual improvement in egg production for the ring necked pheasant was approximately two eggs.

In projecting how greater improvement could be made in the future, it appears advisable to place more selection pressure on the males selected. With the present system both the males and females were saved from dams that were in the top 29 percent based on their egg production. Since only one male is needed for each four females, the males could be restricted to coming from the top 15 percent of the dams. The value for 15 percent is 1.61. In our data the standard deviation was 25.2. Thus, if the rooster came from the top 15 percent the expected selection differential would be 40.3. The dams selection differential would still be 15.8. This would give an overall selection differential of 29.4. The increase of 13.6 in the selection differential should increase the rate of improvement in egg production.

Hertability estimate of egg production was made using realized hertability, regression of offspring on dams, and variance components. The component of this indicates that in this study the estimate of hertability approximately .25.

The phenotypic correlation between egg production and other traits was approximately .15 for all traits except livability it was -.15.

Thus, there does not appear to be a close phenotypic or genetic correlation between egg production and other traits.

APPENDIX

APPENDIX D

Composition of Pheasant Grower Ration

PG-72

Ingredients	Pounds/Ton
Corn	1090
Soybean meal, 49%	560
Wheat middlings	150
Alfalfa, 17%	60
Meat & Bone meal, 50%	60
Salt	5
Dicalcium phosphate	30
Limestone	30
Premix*	15
TOTAL	2000

Calculated Analysis

Crude Protein, %	22.00
Fat, %	3.15
Fiber, %	3.64
Calcium, %	1.43
Phosphorus, available %	.63
M.E., Cal/lb.	1269
P.E., Cal/lb.	903

*Premix 5004, available from Dawes.

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