AN ABSTRACT OF THE THESIS OF

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Title: Single Gene Effects in Chickens (Gallus gallus domesticus)

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Abstract approved: _____   _____
                           James A. Harper

I.   EFFECTS OF THE SEX-LINKED DWARFING GENE (dw) ON GROWTH
     AND REPRODUCTION IN WHITE LEGHORN HENS: PURE LINE AND
     RECIPROCAL CROSSES FED TWO DIETS

     Two lines of chickens, the OSU random-bred dwarf Leghorn popu-
lation (D) and Shaver Starcross "288" Leghorns (S), were mated with-
in line and reciprocally to produce normal (SS, SD) and dwarf (DS,
DD) female progeny. At 18 weeks of age, half the pullets from
each line and cross were fed a basal laying ration with 15% protein
and remaining birds received the basal ration with .1% supplemental
methionine.
     Methionine supplementation significantly increased egg weights
at 35 and 62 weeks of age for all lines and crosses but had no
effect on other growth or reproductive traits. From four to 64
weeks of age, dwarf females (DS, DD) showed lower body weights
than normals (SS, SD). Dwarf hens (DS, DD) also showed reduced
percent hen - day egg production and egg weights compared to normal-
sized hens. The feed efficiency of dwarf layers was better than
normal hens.

II. EFFECTS OF THE SEX-LINKED DWARFING GENE (dw) ON GROWTH
     AND REPRODUCTION IN WHITE LEGHORN HENS: PERFORMANCE OF
     NORMAL AND DWARF SISTERS

Hemizygous dwarf females were artificially inseminated with
semen individually collected from heterozygous males to produce
full-sib normal and dwarf sisters. The parent birds were derived
from crosses between an OSU random-bred dwarf male line and Shaver
Starcross "288". Normal birds had significantly heavier body
weights and longer shank lengths than dwarfs at all ages examined.
No significant differences in age at sexual maturity were observed.
Percent egg production was significantly greater for normals than
dwarfs (77% vs. 67%, respectively). Egg weights were heavier for
normals than dwarfs at 35 weeks (60g vs. 54g, respectively) and
58 weeks (64g vs. 59g, respectively) of age. There were no con-
sistent differences in egg shell quality between normals and
dwarfs. Feed efficiency results were not consistent, while percent
mortality was lower in dwarfs compared to normals.

III. EFFECTS OF THE BLUE EGG-SHELL GENE ON EGG QUALITY AND
     OTHER ECONOMIC TRAITS IN THE CHICKEN

Araucana females (OO) homozygous dominant for the blue egg-
shell allele were mated to homozygous recessive (oo) Shaver Star-
cross "288" males to produce F1 hybrids heterozygous at the blue
egg-shell locus. F1 females were backcrossed to Shaver males pro-
ducing full-sib sisters, half of which were blue egg layers and
half white egg layers.
    The white egg layers had a significantly higher percent egg
production than the blue egg layers (82% vs. 79%). No significant
differences (P > .05) between white and blue egg layers were found
for shell quality, shell thickness, albumen weight, yolk weight,
or yolk cholesterol.

SINGLE GENE EFFECTS IN CHICKENS

(<u>Gallus</u> <u>gallus</u> <u>domesticus</u>)

by

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(Gallus gallus domesticus)

CHAPTER I

INTRODUCTION

The reproductive performance of layer-type chickens has been improved dramatically through intensive genetic selection within the last eighty years (Warren, 1958). Genetic progress for increased egg number and size has slowed down, and breeding emphasis has shifted towards improving feed efficiency and egg shell quality. Since seventy-five percent of the cost of egg production can be attributed to feed costs, this provides great potential for increased production efficiency. Also, as feed cost increases, so does the need to improve feed efficiency. Poor shell quality has accompanied improvements in egg number and size. Losses due to egg shell breakage have been estimated at 250 million dollars annually in the United States alone (Buss, 1978), making this a major concern of breeders.

Genetic improvement in poultry might be accomplished more easily and rapidly by selection for single genes with major effects rather than by selection for polygenes. Major genes offering potential for improved feed efficiency and egg quality are the sex-linked recessive dwarfing gene (dw) and the autosomal dominant blue egg-shell gene (O). Use of the dwarf gene in poultry has been investigated by researchers more than any other single gene for animal production (Sheldon, 1980). However, no clear agreement has been found on its value or application to the egg industry. The dwarf gene reduces body weight, thereby reducing the amount of feed consumed, while the blue egg-shell gene causes a pigment to be deposited throughout the shell of an egg that directly or indirectly influences egg shell quality. Further evaluations of the effect of

these genes on layer performance and egg shell quality are needed before their commercial application can be advocated. Although blue-shelled eggs would not likely be acceptable to consumers, determination of how the blue gene influences egg quality would provide needed information on mechanisms associated with improved egg quality.

LITERATURE REVIEW

The literature on the influence of the dwarfing gene (dw) on growth and reproduction in chickens is voluminous and has been reviewed in detail by Guillaume (1976). The pattern of inheritance for the sex-linked dwarfing gene (dw) in chicken was described by Hutt (1959). The effect of the dwarf gene on growth, reproduction, feed efficiency and nutrient requirements will be discussed. Effects of the blue egg-shell gene on egg quality and composition will also be reviewed.

Dwarf Gene Effects on Growth

The dwarfing gene exerts its influence on body size in a progressive manner. Normal and dwarf chicks hatching from the same size eggs will have similar initial body weights (Hutt, 1949; Rajaratnam et al., 1969; Ricard, 1971), with dwarf birds showing a depressed muscular and skeletal growth to the age of sexual maturity. Thereafter the difference between dwarfs and normals remains constant (Reddy and Siegel, 1977). The depressive effects of the dwarf gene on growth are influenced by the genetic background of the bird as reported by several researchers (Tables I.1 and I.2). The dwarf gene, when placed in the genome of a large-bodied, broiler-type bird, reduces body weight less than when it is placed in the genetic background of a small-bodied, layer-type bird.

Dwarf Gene Effects on Reproduction

The effect of the dwarf gene on age at sexual maturity and egg production varies depending on its interaction with the background genome. Dwarf layer-type hens mature later than normal-sized layers (Table I.1), while the dwarf broiler-type chickens

TABLE I.1 Dwarf gene effects[1] on growth and reproductive traits in layer-type chickens

Author	Year	Age (weeks)	Body weight	Shank length	Egg production	Egg weight	Sexual maturity
Hutt	1959	22	-30.0	--	-15.3	-10.0	+11.3
Bernier and Arscott	1960	48	-37.0	--	-18.0	-10.0	--
Bernier and Arscott	1966	8	-28.2	-14.4	--	--	--
Bernier and Arscott	1966	17	-26.8	-21.4	--	--	--
Quisenberry et al.	1969	48	-31.4	--	-24.0	- 9.6	--
Selvarajah et al.	1970	24	--	--	-13.8	-11.5	+ 5.0
Selvarajah	1971	44	--	--	-11.0	--	--
Merat	1971	--	--	--	-15.0	--	--
Bernier and Arscott	1972	64	-36.0	--	-17.0	-11.0	+ 5.0
Polkinghorne and Lowe	1973	18-66	-31.6	--	-10.2	-11.3	+ 5.0
French and Nordskog	1973	22	-36.8	-29.5	- 3.8	-10.1	--
Dorminey et al.	1974	24	-16.6	--	-10.0	- 2.9	--
Horst and Petersen	1977	40	-28.6	--	-12.8	- 4.5	--
Reddy and Siegel	1977	35	-43.0	-28.0	-53.0	-15.0	+ 4.0
Cherry and Siegel	1978	38	-51.0	-35.0	--	--	--
AVERAGE	--	--	-33.1	-25.7	-17.6	- 9.6	+ 6.0

[1]Percent deviation from normal type chicken.

TABLE I.2 Dwarf gene effects[1] on growth and reproductive traits in broiler-type chickens

Author	Year	Age (weeks)	Body weight	Shank length	Egg production	Egg weight	Sexual maturity
Jaap	1968	8	-29.0	--	--	--	--
Jaap and Mohammadian	1969	36	-18.8	--	--	--	--
Mohammadian	1970	8	-28.1	--	--	--	--
Ricard and Cochez	1971	36	-30.0	--	+ 8.9	--	- 7.0
Mohammadian and Jaap	1972	8	-37.1	-21.0	--	--	--
Chambers et al.	1974	8	- 4.1	--	+ 6.2	- 7.7	--
Reddy and Siegel	1977	35	-26.0	-21.0	+ 8.0	- 5.0	- 3.0
Cherry and Siegel	1978	38	-32.0	-32.0	--	--	--
AVERAGE	--	--	-25.6	-24.7	+ 7.7	- 6.4	- 5.0

[1]Percent deviation from normal type chicken.

mature earlier than their normal-sized counterparts (Table I.2). The sexual maturity delaying effect of the dwarf gene in layers has been viewed negatively by commercial breeders, and this has hindered commercial use of the dw gene (Horst and Petersen, 1977). Ngam (1980), however, has shown that this negative pleiotropic effect can be eliminated through polygenic selection for early sexual maturity, demonstrating an epistatic relationship between the dwarf gene and sexual maturity genes.

Dwarf layers lay fewer eggs annually than normal size layers (Table I.1). The dwarf gene, when placed in a layer-type bird, increases the incidence of defective eggs (i.e., membranous and soft shelled eggs) at the expense of normal eggs (Reddy and Siegel, 1977; Benoff, 1980), showing that dwarf hens have an unrealized reproductive potential. Improvements in the egg-laying capability of the dwarf layer have been made through both genetic selection (Ngam, 1980) and environmental manipulation (Cherry and Siegel, 1978; Cherry et al, 1978).

The dwarf gene effects on egg production in large-bodied birds are opposite to those described above. Dwarf broiler-type hens lay more eggs than normal broiler hens (Table I.2). The positive influence of the dwarf gene on egg production in broiler hens has been attributed to its regulatory effects on ovulation (Jaap and Mohammadian, 1969; Reddy and Siegel, 1977). It could also be attributed to the dwarf gene coming from a layer population or an interaction between the gene and the broiler-type genetic background.

Egg size of dwarf hens is depressed regardless of the genetic background of the bird. However, dwarf birds do lay larger eggs in relation to their body weight than do normal-sized hens (Cherry et al., 1978). Eggs of dwarf hens have smaller yolks and less albumen than eggs from normal hens; but when expressed as a percent of total egg, there were no differences in egg component proportions between dwarf and normal eggs (Cherry et al., 1978). The

reduced egg size of a dwarf hen is in part due to the shorter length of its oviduct (Benoff and Renden, 1980).

Dwarf Gene Effects on Feed Efficiency and Mortality

Most studies comparing dwarf with normal hens demonstrate improved feed efficiencies for the dwarfs (Table I.3). Bernier and Arscott (1960) reported that dwarf layers produced more egg mass per unit of feed consumed than did their normal siblings. They hypothesized that the reduced body size of the dwarf required less feed for body maintenance functions and therefore allowed a greater portion of the feed consumed to be used for reproductive effort (Bernier and Arscott, 1972). In two 2 x 2 diallele crosses between normal and dwarf lines of chickens, French and Nordskog (1973) showed that the reproductive efficiency of the dwarf individuals was due not to the dwarf gene per se but to the reduced body size of the dwarf hen. They found that hens with similar body weights, regardless of whether they were dwarf or normal, had similar feed conversions. They recommended that polygenic selection for small body weight in layers would be effective in improving feed efficiency without having to cope with the negative pleiotropic effects of the dwarf gene. Consequently, polygenic selection for small body size has prevailed over the use of the dwarf gene to obtain small-bodied layer-type birds.

The dwarf gene evidently has a predominantly beneficial influence on mortality and disease resistance. The effect of the dwarf gene in decreasing percent mortality has been documented by several researchers (Table I.4).

The Dwarf Gene and Nutrition

The nutrient requirements of dwarf hens appear to differ from those of normal hens indicating a genotype-environment interaction.

TABLE I.3 Effect of the dw gene on feed efficiency[1] of laying hens

Author	Year	Normal	Dwarf	% deviation from normal
Selvarjah et al.	1970	2.8	2.5	-10.7
Bernier and Arscott	1972	3.9	2.9	-25.6
Quisenberry	1972	2.6	2.5	- 3.8
French and Nordskog	1973	2.7	2.5	- 7.4
Polkinghorne and Lowe	1973	3.4	3.1	- 8.8
McClung and Jones	1973	2.7	2.7	0.0
Dorminey et al.	1974	3.0	2.7	-10.0
Horst and Petersen	1977	2.4	2.2	- 3.3
AVERAGE	--	2.9	2.6	- 9.3

[1]Unit of feed consumed per unit of egg mass produced.

TABLE I.4 Effect of the dw gene on laying mortality

Author	Year	Normal	Dwarf	% deviation from normal
Hutt	1959	14.9	10.6	- 29
Bernier and Arscott	1960	17.0	5.0	- 71
Quisenberry	1972	13.4	9.3	- 31
Polkinghorne and Lowe	1973	8.3	5.0	- 40
Dorminey et al.[1]	1974	5.4	16.5	+ 67

[1]Bird density study.

Egg size from dwarf hens can be improved significantly when protein
is fed at levels higher than those considered appropriate for
normal-type layers (Arscott and Bernier, 1968; Quisenberry et al.,
1969; Quisenberry, 1972; Guillaume, 1971) although such treatment
has little effect on other reproductive characteristics. Similar
improvements in the egg size of dwarfs can be obtained with the
addition of only .1% methionine in the ration (Arscott and Bernier,
1968; Bernier and Arscott, 1972). The addition of a single amino
acid compared with increased protein in a ration is more practical
since protein is the most costly component in a ration.

The Blue Egg-Shell Gene and Its Effects
on Egg Quality and Composition

The blue egg-shell gene (O), indigenous to Araucanas, a South
American breed of fowl, was found to be autosomal dominant by
Punnett (1933). Blue pigment, a biochemical product of the blue
egg-shell gene, is deposited in the shell of eggs from birds homo-
zygous or heterozygous for the "O" allele. Since the pigment per-
vades the entire shell structure of the egg as contrasted to
porphyrin deposited on the shell, it may in some way influence
shell strength and quality. Cunningham (1977) reported that
Araucana eggs have thicker shells than either Leghorn or Plymouth
Rock eggs. Whether this egg shell difference is due directly to
the blue egg-shell gene or to the background genotype of these
birds is not known.

Relatively few studies have been conducted to evaluate the
effects of the blue gene on egg quality and on reproductive per-
formance. Confusion, however, regarding the composition of the
blue eggs from Araucana hens has been caused by several lay pub-
lications. Hickman (1974) reported that such blue eggs possess
"no cholesterol, 20 percent more protein, and 20 percent more
iron." As a result of this statement, several studies have been
conducted to determine the composition of Araucana or blue eggs.

Electrophoretic or proximate analyses of the chemical composition of albumen and yolk have revealed no difference between Araucana, Leghorn or Plymouth Rock eggs (Cunningham, 1977). Araucana eggs do have a larger yolk and less albumen for a given egg size than do eggs from Leghorns (Simmons and Somes, 1978). Anglin and Briles (1980) found that the amount of cholesterol per gram of yolk was similar among eggs from purebred Araucana (AU), White Leghorn (WL), and Rhode Island Red (RIR) hens, although eggs from hens obtained by crosses of AU x RIR showed a significant reduction in the level of cholesterol.

Differences that have been observed between Araucana eggs and eggs from other breeds of domestic fowl cannot be attributed to the blue egg gene alone since the gene was confounded with genetic background.

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CHAPTER II

EFFECTS OF THE SEX-LINKED DWARFING GENE (<u>dw</u>) ON
GROWTH AND REPRODUCTION IN WHITE LEGHORN HENS

1. PURE LINE AND RECIPROCAL CROSSES FED TWO DIETS[1]

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ABSTRACT

Two lines of chickens, the OSU random-bred dwarf Leghorn popu-
lation (D) and Shaver Starcross "288" Leghorns (S), were mated
within line and reciprocally to produce normal (SS,SD) and dwarf
(DS,DD) female progeny. All progeny were reared similarly until
18 weeks of age when birds were transferred to individual cages.
At 18 weeks of age, half the pullets from each line and cross were
fed a basal laying ration containing of 15% protein while the re-
maining birds received the basal ration with .1% supplemental
methionine.

Methionine supplementation significantly increased egg weights
at 35 and 62 weeks of age for all lines and crosses but had no
effect on other growth or reproductive traits. From the 4th week
to 64 weeks of age, dwarf females (DS,DD) had lower body weights
than normals (SS,SD). Dwarf hens (DS,DD) also had reduced percent
hen-day egg production and egg weight compared to normal-sized hens.
The feed efficiency of dwarf layers was better than normal hens in
units of egg mass and per dozen eggs. There was no significant diet
x genotype interaction.

INTRODUCTION

The influence of the sex-linked dwarfing gene (dw) on growth
and reproduction in chickens has been well documented and shown
to be somewhat dependent on the genetic background of the bird
(Guillaume, 1976). Generally speaking, the dwarfing gene in layer
type stock depresses growth by approximately 30% (Hutt, 1959),
delays age at sexual maturity by approximately 5 days (Bernier and
Arscott, 1972), reduces egg size due primarily to the reduction in
body size (Benoff and Renden, 1980) and decreases egg numbers
(Bernier and Arscott, 1960; French and Nordskog, 1973). Many of
these deficits associated with the presence of the dwarfing gene
in layers can be alleviated through polygenic selection. Ngam
(1980) found that 13 generations of selection for earlier maturity,
greater egg number and increased egg size dramatically decreased
age at sexual maturity (from 32 to 22 weeks of age) and increased
egg numbers (from 51 to 218 eggs).

Bernier and Arscott (1972) reported that dwarf layers, in
spite of their reproductive performance, were more efficient than
normal-sized layers, and attributed this efficiency to the lower
body maintenance requirement of the smaller bird. French and
Nordskog (1973), however, compared the reproductive efficiency
of dwarf and normal layers produced from pure line and reciprocal
crosses of small-bodied and large-bodied dwarf and normal laying
hens. Their data suggested that improvements in feed efficiency
of the dwarf birds were due to their smaller body size and not
the dwarfing gene per se.

The objectives of this study were to investigate the effects
of the dwarfing gene, (dw), on growth and reproduction in pure
line and reciprocal cross female progeny. The source of the
dwarf gene was the OSU dwarf Leghorn population, a population
whose background genome had been modified to the extent that these
birds performed more like commercial layers (Ngam, 1980) than

dwarf birds with overall poor performance used in similar studies (French and Nordskog, 1973). Arscott and Bernier (1968) and Bernier and Arscott (1972) observed that dwarf Leghorns laid larger eggs in response to a diet supplemented with .1% methionine but that egg sizes from normal-sized layers were not altered by the addition of methionine. These data suggested a genotype-environment interaction for egg size. Consequently, this study further investigated the nature of such interactions by providing all lines and crosses with two diets differing in methionine content.

MATERIALS AND METHODS

Stocks

Female progeny utilized in this study were obtained from within line matings and reciprocal crosses of Shaver Starcross "288" (S) and the OSU random-bred dwarf Leghorn population (D). Population D was homozygous for the sex-linked dwarf gene (dw) and had undergone 13 generations of selection for increased egg number, increased egg size and earlier sexual maturity (Bernier and Arscott, 1972). Immediately prior to this study D had undergone one generation of random mating. Although the lines were not pure stock, the term pure will be used in the text to represent within line matings. Parental matings and the genotypes, phenotypes and number of progeny utilized in this study are presented in Table II.1 Only data from hens surviving to 64 weeks of age (N=471) were analyzed.

Management

The chicks were wing banded and sexed upon hatching, and females were brooded together until eight weeks of age. In order to reduce a possible genotype-environment correlation due to the competition between heavy and light individuals for common resources, birds were sorted into two weight classes (high and low body weight) at eight weeks of age and reared within a weight class until housing at 18 weeks of age. All birds received the same starter, developer I and developer II rations to 18 weeks of age. At 18 weeks of age, hens were housed in individual cages. For purposes of obtaining feed consumption data, hens within a line or cross were housed adjacently forming a block. There were 8, 9, 10, and 11 blocks for DS, DD, SS and SD birds, respectively. These blocks were randomly distributed among the cage units so as

to minimize possible location effects. One-half of the blocks of
birds within each line or cross was fed a standard layer ration
(Normal diet), while the other half received the same standard
ration supplemented with .1% methionine (Dwarf diet),(Table II.2).
Caged birds received 14 hr of illumination daily, were fed ad
libitum and were provided with water for eight 15-minute periods
at 2 hr intervals during the light period.

Measurements

Individual body weights were obtained at 1, 2, 4, 8, 16, 32,
and 64 weeks of age. Shank length was measured at 8 weeks of age
for each bird. Eggs were collected from each hen during three-day
periods at 35 and 62 weeks of age, and their weights, specific
gravities and Haugh units were determined. The average egg
weight, specific gravity and Haugh unit for each hen at each age
were the values used in the statistical analyses. For purposes
of statistical analysis egg production was divided into two pro-
duction periods: the initial period being from sexual maturity
to 280 d of age and the residual period from 281 d to 449 d of age.
Feed consumption was determined for each line x diet grouping
during two 28-day periods, first from 33-37 weeks and second from
60-64 weeks of age.

Statistical Analyses

Body weights obtained after 18 weeks of age, age at sexual
maturity, percent hen-day egg production for the initial, resi-
dual and total production periods, weights, specific gravities
and Haugh units were analyzed according to the following model to
determine the significance of line and diet effects.

$$Y_{ijk} = \mu + D_i + L_j + (DL)_{ij} + E_{ijk}$$

where: μ = overall mean

D_i = the ith diet effect, i = 1, 2

L_j = the jth line effect, j = 1, 2, 3, 4

$(DL)_{ij}$ = the ith diet by j^{th} line interaction

E_{ijk} = random error

The significance of differences in body weights and shank length before 18 weeks of age among lines were determined using a simpler model where the effects of diets and the interaction between lines and diets were omitted since pullets were fed uniformly prior to this age.

To determine the influence of line, heterosis and dwarfing gene (i.e., sex chromosome) effects on body weights, shank length and reproductive measures, the following statistical model was used:

$$Y_{ijkl} = \mu + G_i + Z_j + H_k + E_{ijkl}$$

where: μ = overall mean

G_i = genetic effect of line

Z_j = effect of the sex chromosome of sire line j in the cross

H_k = heterosis effect of cross vs. line

E_{ijkl} = random error due to differences of individuals

The matrix of coefficients for estimating line, heterotic and

sex chromosome effects proposed by French (1972) and modified here
is shown in Table II.3. The four crosses are then:

$$Y_{ss.} = \mu + G_s \qquad\qquad + H_1$$

$$Y_{sd.} = \mu + \tfrac{1}{2}G_s + \tfrac{1}{2}G_d + Z_s + H_c$$

$$Y_{ds.} = \mu + \tfrac{1}{2}G_s + \tfrac{1}{2}G_d + Z_d + H_c$$

$$Y_{dd.} = \mu + G_d \qquad\qquad + H_1$$

Since autosomal gene effects and maternal effects are completely
confounded in this study,

$$\hat{G} = (\hat{Y}_{ss.} - \hat{Y}_{dd.})/2 \qquad \text{estimates } G_s - G_d,$$

$$\hat{Z} = (\hat{Y}_{sd.} - \hat{Y}_{ds.})/2 \qquad \text{estimates } Z_s - Z_d$$

where the sex chromosome and dwarf gene are confounded and

$$\hat{H} = \tfrac{1}{2}\left[(\hat{Y}_{sd.} + \hat{Y}_{ds.}) - (\hat{Y}_{ss.} + \hat{Y}_{dd.})\right] \qquad \text{estimates } H_c - H_1.$$

To show the reduction in traits due to the dwarfing gene (dw)
a relative dwarf effect is expressed as a percentage. Effects of
the dwarfing gene (and associated Z chromosome) were expressed as

$$\hat{dw} = \left[(\hat{Y}_{sd.} - \hat{Y}_{ds.})/\hat{Y}_{sd.}\right]\ (100\%).$$

RESULTS AND DISCUSSION

Diet Effects

Egg weights at 35 and 62 weeks of age were the only measured variables influenced by the two rations fed (Table II.4). These findings are in agreement in part with those of Arscott and Bernier (1968) and Bernier and Arscott (1972) who observed improvements in egg weight of dwarf hens with the addition of .1% methionine. Egg weight is known to be associated with body weight (Benoff and Renden, 1980) although in this experiment increases in egg weight at 35 and 62 weeks of age due to the supplemented methionine were not due to changes in body weight at these ages (Table II.4). All lines and crosses responded similarly to the added methionine as indicated by the lack of a significant line x diet interaction for all traits measured.

Line Effects

1. Growth

Significant differences among the lines in body weight were observed at all ages (Table II.5). Phenotypically normal-sized hens were heavier than dwarf individuals at all ages measured with the exception of SD birds which were lighter than dwarf birds (i.e., DS) at 1 week of age. Many studies have shown (Hutt, 1949; Rajaratnam et al., 1969; Ricard, 1971) a strong initial positive relationship between chick weight and egg weight. Such maternal effects diminish with age of the chick. SD birds originated from eggs of dwarf-sized dams (Table II.1). These eggs were not weighed but probably were smaller than eggs from normal-sized dams. Consequently, chicks hatching from these eggs were expected to have lower initial body weights.

Within phenotypes (i.e., dwarf vs. dwarf and normal-sized

vs. normal-sized), cross line birds grew more rapidly than their pure line counterparts (Table II.5), indicating a certain amount of dominant or epistatic gene action for growth rate regardless of the presence or absence of the dwarfing allele, dw. The degree of heterosis is presented in Table II.6.

Genetically, the only difference between SD and DS birds was the Z chromosome and presumably the major difference in Z chromosomes was the allelomorph at the dw locus. Therefore, the effect of the dwarf gene on growth rate was determined by comparing SD and DS (Table II.6). Initially (i.e., at 1 and 2 weeks of age), dwarf birds were heavier than non-dwarf birds which was most probably due to the maternal influence of egg size (Table II.5). By 8 weeks of age, the dwarf gene depressed body weight of the dwarf birds by about 26%.

Phenotypically dwarf birds had smaller body frames than normal-sized birds as indicated by 8-week shank length. Shank lengths were 78, 80, 69, and 68 mm for SS, SD, DS and DD line birds respectively (Table II.5). The reduction in shank length attributable to the dwarf allele was 13.8%.

2. Reproduction

Significant differences in age at sexual maturity and hen-day egg production among the lines were observed (Table II.7). Hens carrying the dwarfing gene (i.e., DS and DD) matured at an age intermediate to the age of maturity for non-dwarf birds (SS and SD). Normal hens (SD) matured significantly earlier than normal SS hens. This could be explained by heterosis (Table II.8) in the SD cross. Age at sexual maturity for the dwarf progeny groups (DS and DD) was nearly equal. The DS hens would be expected to have intermediate age at sexual maturity (155 d) between that of SS and DD hens. However, heterosis could be a possible explanation for the small difference since French and Nordskog (1973) reported a similar heterotic effect for comparable

body size birds. The effect of the dwarf gene per se was to delay sexual maturity (Table II.7). The negative value for sexual maturity (Table II.8) implies that the crosses were heterotic for earlier maturity and in contrast, the dwarf gene evidently causes later sexual maturity (French, 1972).

Hen-day egg production differed significantly among the lines (Table II.7) with phenotypically dwarf-sized hens (i.e., DS and DD) laying significantly fewer eggs than the normal-sized layers. The dwarf gene per se depressed egg production by more than 10% for the entire production period (Table II.7). A heterotic effect for increased egg production was observed (Table II.8). The negative effect of the dwarf gene on egg production has been reported by several researchers including Bernier and Arscott (1972) and French and Hordskog (1973). However, percent hen-day egg production of dwarfs was considerably higher than that reported for dwarf chickens of comparable size (French and Nordskog, 1973; Reddy and Siegel, 1977). Higher egg production could be attributed to long-term selection for earlier maturity and greater egg number (Ngam, 1980). A similar heterotic effect for increased egg production of comparable body size birds was reported by French and Nordskog (1973).

As there were no significant interactions observed in egg weight between lines and diets (Table II.4), sex chromosome effects and heterotic effects were determined using data pooled across diets. Dwarf birds laid significantly smaller eggs than normal-sized hens at 35 and 62 weeks of age (Table II.7). Benoff and Renden (1980) observed that smaller-bodied chickens had a reduced oviduct surface area particularly in the magnum, which contributed to the formation of smaller eggs. The dwarf gene in this study reduced egg size by approximately 9% (Table II.7) but reduced body size by 32%, indicating that dwarf hens lay larger eggs for their body size than normal-sized hens. A slight heterotic effect towards larger egg size was observed in this study (Table II.8). This result agrees with that of French

and Nordskog (1973) who reported a similar heterotic effect in their small Leghorn line crosses.

Little difference was observed among the lines in internal egg quality as evidenced by the magnitudes of the Haugh unit measurements (Table II.7). The dwarf cross line (DS) exhibited a higher quality egg at 35 weeks of age than the other lines, however, no differences among lines in Haugh units were observed at 62 weeks of age. The dwarf gene tended to improve egg interior quality slightly (Table II.8) and a slight heterotic effect towards higher quality was observed (Table II.8).

Cross-line dwarf hens (DS) laid eggs with significantly better shell quality as determined by specific gravity than hens derived from other matings (Table II.7) although the dwarf gene per se had little influence on shell quality. Smaller egg size of dwarf hens (DS) compared to that of normal hens (SS and SD) may partially have accounted for the better shell quality (Hamilton, 1978).

3. Feed Consumption

Feed consumption measured by line, diet and age are presented in Table II.9. Dwarf hens (DS and DD) consumed less feed than normal hens (SS and SD) in all cases. Cross-line dwarf hens (DS) had the best feed efficiency based on unit of egg per unit of egg mass and per dozen eggs than hens derived from other matings. Body weights of dwarf hens (DS and DD) at 32 and 64 weeks of age were not significantly different (Table II.5), which shows body weight per se cannot be the sole explanation for better feed efficiency of DS hens. The lower feed efficiency of DD hens could be attributed to their lower rate of production (French and Nordskog, 1973). When comparison is made between normal hens (SD) and dwarf hens (DS), a better feed efficiency is obtained due to the dwarfing gene (dw). Results from this study indicate a better feed efficiency for dwarfs which is in agreement with the

report of others (Selvarajah et al., 1970; Bernier and Arscott, 1972; Polkinghorne and Lowe, 1973).

TABLE II.1 Parental matings and phenotype, genotype[1] and number of progeny obtained

Parental matings		Progeny			
Sire	Dam	Line or cross	Genotype	Phenotype	N[2]
Shaver	Shaver	SS	DW-	Normal	129
Shaver	OSU dwarf	SD	DW-	Normal	143
OSU dwarf	Shaver	DS	dw-	Dwarf	93
OSU dwarf	OSU dwarf	DD	dw-	Dwarf	106

[1]With respect to the dwarf locus on the sex chromosome.

[2]Number of hens surviving to 64 weeks of age.

TABLE II.2   Ingredient composition of layer diets

Ingredient name	Diet	
	Dwarf	Normal
	%	
Corn, yellow	70.50	70.61
Soybean meal (47.5%)	18.00	17.99
Alfalfa meal, dehydrated (17%)	2.50	2.50
Defluorinated rock phosphate	2.00	2.00
Limestone flour	3.65	3.65
Oystershell flour	2.50	2.50
Salt, iodized	0.50	0.50
Trace mineral mix[1]	0.05	0.05
Vitamin premix[2]	0.20	0.20
DL-methionine	0.10	--
TOTAL	100.00	100.00
Calculated analysis:		
ME (kcal/kg)	2896.00	2900.00
Protein	15.00	15.00
Methionine	0.36	0.26
Cystine	0.28	0.28

[1]Trace mineral mix provides per kg ration: Mn, 50 mg; Fe, 2 mg; Cu, 0.2 mg; Zn, 27.5 mg; Co, 0.2 mg.

[2]Vitamin premix provides per kg ration: Vit A, 3300 IU; Vit D-3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22.0 mg; choline, 190.0 mg; Vit B-12, 5.5 mcg; Vit E, 1.1 IU; Vit K, 0.55 mg; folic acid, 0.22 mg; ethoxyquin, 0.06 g.

TABLE II.3 Matrix of coefficients for parameters in the model[1]

Mean	Line and cross	μ	G_s	G_d	Z_s	Z_d	H_1[3]	H_c[4]
$Y_{ss.}$	SS	1	1	0	0	0	1	0
$Y_{sd.}$	SD	1	$\frac{1}{2}$	$\frac{1}{2}$	1	0	0	1
$Y_{ds.}$	DS	1	$\frac{1}{2}$	$\frac{1}{2}$	0	1	0	1
$Y_{dd.}$	DD	1	0	1	0	0	1	0

[1] $Y_{ijkl} = \mu + G_i + Z_j + H_k + E_{ijkl}$.

where μ = overall mean.

G_i = genetic effect of line.

Z_j = effect of the sex chromosome of sire line j in the cross.

H_k = heterosis effect of cross vs. line.

E_{ijkl} = random error due to differences of individuals.

[2] Estimable definitions: $\hat{G} = G_s - G_d$; $\hat{Z} = Z_s - Z_d$; and $\hat{H} = H_c - H_1$.

[3] Line.

[4] Cross.

TABLE II.4 Egg weights and body weights at comparable ages by line, cross and diet

Trait		Dwarf Diet[1]					Normal Diet				
Line and cross	SS	SD	*DS	*DD	$\overline{X}$ [2]	SS	SD	*DS	*DD	$\overline{X}$
Egg weight (g)											
35-week	61	60	55	54	57^a	58	59	52	52	55^b
62-week	65	64	59	57	61^a	63	63	57	56	60^b
Body weight (g)											
32-week	1721	1816	1249	1204	1498^a	1733	1777	1229	1213	1488^a
64-week	1783	1945	1299	1288	1579^a	1779	1898	1265	1269	1553^a

[1]Diet supplemented with .1% methionine.

[2]Means within a row across diets with the same superscript are not significantly different at P > .05.

*Dwarf progeny.

TABLE II.5 Least squares means[1] and percent dwarf gene effect on body weight (BW,g) at various ages and shank length (SL,mm) for pure line and reciprocal cross female progeny

Growth Trait (age)	Line and cross				Dwarf effect[2] (%)
	SS	SD	*DS	*DD	
BW (1 week)	50^a	42^c	45^b	39^d	7.1
BW (2 weeks)	80^a	73^b	73^b	65^c	.0
BW (4 weeks)	241^a	233^b	204^c	185^d	-12.4
BW (8 weeks)	566^a	577^a	430^b	406^c	-25.5
BW (16 weeks)	1120^b	1172^a	806^c	767^d	-31.2
BW† (32 weeks)	1728^b	1797^a	1241^c	1210^c	-30.9
BW† (64 weeks)	1781^b	1922^a	1285^c	1276^c	-33.1
SL (8 weeks)	78^b	80^a	69^c	68^d	-13.8

[1] Means within a row with the same superscripts are not significantly different at P > .05.

[2] $\left(\frac{DS-SD}{SD}\right) \times 100$.

*Dwarf progeny.

†Values pooled across diets.

TABLE II.6 Estimates of line ($\hat{G}$), heterosis ($\hat{H}$) and dwarf ($\hat{Z}$) effects on body weight (BW,g) and shank length (SL,mm)

Trait		$\hat{G}$	$\hat{H}$	$\hat{Z}$
BW	(1 week)	10.9	4.8	1.3
BW	(2 weeks)	15.3	8.7	-0.2
BW	(4 weeks)	56.2	33.6	-14.3
BW	(8 weeks)	160.4	97.7	-73.2
BW	(16 weeks)	352.8	221.6	-183.0
BW†	(32 weeks)	516.8	307.5	-278.4
BW†	(64 weeks)	502.0	323.1	-319.4
SL	(8 weeks)	10.4	7.0	-5.4

†Pooled across two diets.

TABLE II.7 Least squares means[1] and percent dwarf gene effect on various reproductive traits for pure line and reciprocal cross female progeny, data pooled across diets

Reproductive trait	Line and cross				Dwarf effect[5] (%)
	SS	SD	*DS	*DD	
Age at sexual maturity (days)	158[a]	146[c]	153[b]	152[b]	4.8
% Hen-day egg production					
Initial[2]	86[a]	85[a]	77[b]	72[c]	- 9.4
Residual[3]	70[a]	74[a]	64[b]	57[c]	-13.5
Total[4]	77[a]	79[a]	70[b]	64[c]	-11.4
Egg weight (g)					
35-week	59[a]	59[a]	54[b]	53[b]	- 8.5
62-week	64[a]	64[a]	58[b]	56[c]	- 9.4
Haugh unit					
35-week	71[b]	71[b]	74[a]	71[b]	4.2
62-week	71[a]	71[a]	72[a]	70[a]	1.4
Specific gravity					
35-week	1.083[b]	1.082[b]	1.084[a]	1.082[b]	.2
62-week	1.076[b]	1.077[b]	1.079[a]	1.076[b]	.2

[1]Means within a row with the same superscript are not significantly different at P > .05.

[2]From sexual maturity to 280 days of age.

[3]From 281 to 449 days of age.

[4]From sexual maturity to 449 days of age.

[5]$\left(\frac{DS-SD}{SD}\right) \times 100.$

* Dwarf progeny.

TABLE II.8   Estimates of line ($\hat{G}$), heterosis ($\hat{H}$) and dwarf ($\hat{Z}$) effects on reproduction and egg characteristics

Trait	$\hat{G}$	$\hat{H}$	$\hat{Z}$
Age at sexual maturity (days)	5.7	-2.6	3.5
% Hen-day egg production			
Initial[1]	13.7	9.0	-3.8
Residual[2]	13.1	11.9	-5.1
Total[3]	12.5	10.1	-4.6
Egg weight (g)			
35-week	6.2	3.4	-2.8
62-week	7.6	4.6	-2.8
Haugh unit			
35-week	- .1	1.3	1.6
62-week	.6	1.3	.8
Specific gravity			
35-week (x 10^5)	111.5	152.6	125.0
62-week (x 10^5)	-52.5	129.5	96.6

[1] From sexual maturity to 280 days of age.

[2] From 281 to 449 days of age.

[3] From sexual maturity to 449 days of age.

TABLE II.9 Feed consumption measures by line, diet and age

Age range (weeks)	Feed consumed per	Diet	Line and cross			
			SS	SD	*DS	*DD
(33-37)	bird/day (g)	Dwarf [1]	124.3	123.0	94.7	97.3
		Normal	123.6	125.2	90.5	87.6
	egg mass[2]	Dwarf	2.4	2.4	2.2	2.6
		Normal	2.4	2.4	2.2	2.3
	doz. eggs[3]	Dwarf	1.7	1.7	1.4	1.7
		Normal	1.6	1.7	1.4	1.5
(60-64)	bird/day (g)	Dwarf	114.4	124.2	86.4	80.6
		Normal	116.3	118.5	85.0	84.1
	egg mass	Dwarf	2.7	2.8	2.5	2.8
		Normal	2.3	2.9	2.5	3.2
	doz. eggs	Dwarf	2.1	2.2	1.7	1.9
		Normal	1.7	2.2	1.7	2.1

[1] Basal diet supplemented with .1% methionine.

[2] g feed/g egg.

[3] kg feed/doz. eggs.

* Dwarf progeny.

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CHAPTER III

EFFECTS OF THE SEX-LINKED DWARFING GENE (dw) ON
GROWTH AND REPRODUCTION IN WHITE LEGHORN HENS

2. PERFORMANCE OF NORMAL AND DWARF SISTERS[1]

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ABSTRACT

Hemizygous dwarf females were artificially inseminated with semen individually collected from heterozygous males to produce full-sib normal and dwarf sisters. The parents were derived from crosses between an OSU random-bred dwarf male line and Shaver Starcross "288." Growth traits (body weight and shank length) and reproductive traits (sexual maturity, egg production, egg weight, specific gravity and Haugh units) were measured in normal and dwarf sisters. Normal birds had significantly heavier body weights and longer shank lengths than dwarfs at all ages examined. No significant differences in age at sexual maturity were observed. Percent egg production was significantly better for normals than dwarfs (77% vs. 67%, respectively). Egg weights were heavier for normals than dwarfs at 35 weeks (60g vs. 54g, respectively) and 58 weeks (64g vs. 59g, respectively) of age. There were no consistent differences in egg-shell quality between normals and dwarfs. Feed efficiency results based on egg mass were not consistent between normals and dwarfs, and percent mortality was lower in dwarfs than in normals.

INTRODUCTION

Considerable amounts of research have shown that smaller bodied layers are more efficient utilizers of feedstuffs than larger-bodied birds (Bernier and Arscott, 1960; French and Nordskog, 1973; Guillaume, 1976; Horst and Petersen, 1977). Genetically, smaller-sized layers can be obtained through polygenic selection for low body weight or through introduction of the sex-linked dwarf gene (dw) into a line of layers. Polygenic selection would take several years to reach a desired body weight, whereas smaller-sized layers could be obtained in one generation by introducing the dwarf gene. A major disadvantages to the use of the dwarfing gene has been its negative pleiotropic effects on sexual maturity, egg production and egg size (Guillaume, 1976). Poor performance of dwarf layers can be improved dramatically through polygenic selection for earlier sexual maturity and increased egg number (Ngam, 1980). By altering the background genome in which the dwarf gene resided through 13 generations of selection, age at sexual maturity was changed from 32 weeks to 22 weeks of age and egg number to 68 weeks of age was improved from 51 to 218 eggs (Ngam, 1980).

This study was designed to determine the effects of the dwarfing gene (dw) on growth and reproduction in White Leghorns. This was accomplished by studying the performance of hens having the same background genome (i.e., full-sib sisters) but differing in the allelomorph at the dwarf locus.

MATERIALS AND METHODS

Forty hemizygous dwarf females were artificially inseminated with semen individually collected from eight males heterozygous at the dwarf locus to produce full-sib sisters with phenotypes in the ratio of 1 normal:1 dwarf. The parent birds were derived from crosses between an OSU random-bred dwarf male line and Shaver Star-cross "288" females (Sadjadi et al., 1982). Chicks were wing-banded and sexed upon hatching, beak-trimmed at 12 days of age and females brooded together until ten weeks of age. At ten weeks of age, birds were segregated and reared in two genotypic classes (normal and dwarf). Genotypic class was determined by measuring body weight and shank length at 10 weeks of age. All birds received the same OSU starter, developer I and developer II rations to 18 weeks of age.

At 18 weeks of age, pullets were housed in a cage unit such that families of half-sib sisters were housed adjacently although in individual cages. All birds were fed ad libitum a laying ration with 15% protein and 2896 kcal/kg M.E. (Sadjadi et al., 1982). Caged pullets received 14 hr of illumination daily and were provided with water for eight 15-minute periods at 2 hr intervals during the light period. Data from 389 hens obtained from three hatches that survived to 60 weeks of age were analyzed in this experiment.

Growth was determined by measuring body weights at 5, 10, 20, 40 and 60 weeks of age and shank length at 10 and 20 weeks of age for individual birds. Daily egg production to 60 weeks of age was determined for each hen. Egg production to 60 weeks of age was divided into two production periods: from sexual maturity to 40 weeks of age (initial period) and from 40 to 60 weeks of age (residual period). Individual egg weight, shell quality (specific gravity) and internal egg quality (Haugh unit) were determined for eggs collected during three days at 35 and 58 weeks of age. The average egg weight, specific gravity and Haugh unit for each hen at each age were the values used in the statistical analyses. Feed consumption was measured for each genotype from hatch 1 during three

28-day periods, first at 33-37 weeks, second at 46-50 weeks and third at 56-60 weeks of age.

To determine the effect of the dwarf gene for each dependent variable, statistical analysis between normal and dwarf siblings were made using analysis of variance on an average full-sib family basis with hatch as a block (Snedecor and Cochran, 1973).

RESULTS AND DISCUSSION

Significant differences in body weight between normal and
dwarf sisters were observed from the first weighing at 5 weeks
(Table III.1) on through to 60 weeks of age. The dwarf gene de-
pressed body weights from 23% to 33% depending on the age of the
hens (Table III.1). In contrast to Sadjadi et al. (1982), the
dwarf gene exerted its influence in growth at an early age. Dwarf
and normal progeny obtained in this study arose from eggs of dwarf-
sized dams. Dwarf-sized progeny studied by Sadjadi et al. (1982),
however, came from normal dams, thereby confounding growth with
genotype and maternal effects. Rath et al. (1980) reported sizable
dwarf gene effects on body weight at an earlier age, results which
are in agreement with those of this study.

Dwarf pullets had reduced shank lengths compared to normal
pullets (Table III.1), but the percent effect of the dwarfing gene
on shank length was less than for body weight. Guillaume (1976)
observed that the dwarf gene exerted differential influence on the
growth of various body parts.

Initial, residual and total percent hen-day egg production of
normal hens were significantly better than their dwarf sisters
(Table III.2). The dwarf gene reduced the total egg production
by 13%, which is similar to other reports in the literature
(Selvarajah et al., 1970; Horst and Petersen, 1977). Quantitative
effects of the dw gene on egg production seem to be caused by de-
layed sexual maturity in some cases, poor persistency of lay (Yoo
et al., 1980), and short clutch length (Merat, 1969); although the
percent hen-day measurement of egg production is free of the age
at sexual maturity component. Normal hens produced significantly
larger eggs compared to dwarf hens at both ages measured (Table
III.2). This can be explained, in part, by the reduced body weight
of the dwarfs since there is a high correlation between body weight
and egg weight (Hogsett and Nordskog, 1958). The ratio of dwarf
egg weight to normal egg weight increased from .90 at 35 weeks of

age to .92 at 58 weeks of age. Similar observations were reported by Guillaume (1976). The internal egg quality (Haugh unit) of eggs from dwarf hens was better than of eggs from normal hens at 35 and 58 weeks of age (Table III.2). Merat (1972) also reported greater albumen height for dwarf hen eggs. Eggs from dwarf hens had better shell quality than those of their normal-sized sisters, which may be related to reduced egg weight or size (Hamilton, 1978). These data are in agreement with those of Polkinghorne and Lowe (1973) and Sadjadi et al. (1982).

Hen-housed livability was 93.4% for the normal hens and 97.2% for the dwarf hens. The dwarf gene increased livability by 4.1%. Similar results of dwarf gene effects were reported by Quisenberry (1972) and Polkinghorne and Lowe (1973). The dwarf gene evidently has a predominantly positive influence on mortality and resistance (Bernier and Arscott, 1972; Polkinghorne and Lowe, 1973).

Feed efficiency, in terms of units of feed per unit of egg mass and dozen eggs is given in Table III.3. Results were not consistent. Superior feed efficiency of dwarf layers has been reported by several researchers including Selvarajah et al., 1970; Bernier and Arscott, 1972; and Sadjadi et al., 1982, but it is not apparent when laying rate is low (McClung et al, 1971; McClung and Jones, 1973; Doran and Quisenberry, 1974). French and Nordskog (1973) indicated that variation in efficiency is due mainly to the differences in rate of production and body weight.

Significant family effects were observed for all variables measured with the exception of age at sexual maturity, indicating that phenotypic variation and probably genetic variation for these traits is still present in this population of birds. Genetic selection likely would improve performance further; although the dwarf gene per se, even when present in an improved background genome, would probably exert negative effects on certain performance characteristics. The dwarf hens better livability and smaller space requirement are advantages which must be weighed economically against reduced performance.

TABLE III.1 Least squares means[1] and percent dwarf gene effects on body weight (BW) and shank length (SL) for normal and dwarf sisters

| Growth trait (age) | Genotype | | Dwarf effect[2] (%) |
	Normal (N=213)	Dwarf (N=176)	
		g	
BW (5 weeks)	314^a	241^b	-23.2
BW (10 weeks)	711^a	479^b	-32.6
BW (20 weeks)	1407^a	963^b	-31.6
BW (40 weeks)	1856^a	1243^b	-33.0
BW (60 weeks)	1968^a	1339^b	-32.0
		mm	
SL (10 weeks)	82^a	67^b	-18.3
SL (20 weeks)	97^a	76^b	-21.6

[1]Means within a row with the same superscript are not significantly different at P > .05.

[2]$\left(\dfrac{\text{dwarf-normal}}{\text{normal}}\right) \times 100.$

TABLE III.2 Least squares means[1] and percent dwarf gene effects on various reproductive traits for normal and dwarf sisters

Reproductive trait	Genotype		Dwarf effect[5] (%)
	Normal (N=213)	Dwarf (N=176)	
Age at sexual maturity (days)	153[a]	152[a]	- .7
% Hen-day egg production			
Initial[2]	83[a]	73[b]	-12.0
Residual[3]	71[a]	62[b]	-12.7
Total[4]	77[a]	67[b]	-13.0
Egg weight (g)			
35-weeks	60[a]	54[b]	-10.0
58-weeks	64[a]	59[b]	- 7.8
Haugh unit			
35-weeks	72[a]	74[a]	2.8
58-weeks	74[a]	75[a]	1.4
Specific gravity			
35-weeks	1.0797[b]	1.0826[a]	.3
58-weeks	1.0745[a]	1.0746[a]	.0
Hen-housed livability (%)	93.4	97.2	4.1

[1] Means within a row with the same superscript are not significantly different at $P > .05$.

[2] From sexual maturity to 280 days of age.

[3] From 281 to 420 days of age.

[4] From sexual maturity to 420 days of age.

[5] $\left(\dfrac{\text{dwarf-normal}}{\text{normal}}\right) \times 100.$

TABLE III.3 Feed efficiency by age and genotype

	Genotype	
Trait	Normal	Dwarf
33-37 weeks of age		
g feed consumed/bird/day	125.3	90.8
g feed/g egg	2.5	2.4
kg feed/doz. eggs	1.8	1.6
46-50 weeks of age		
g feed consumed/bird/day	115.5	90.2
g feed/g egg	2.4	2.6
kg feed/doz. eggs	1.8	1.8
56-60 weeks of age		
g feed consumed/bird/day	95.7	73.3
g feed/g egg	2.2	2.3
kg feed/doz. eggs	1.7	1.7

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CHAPTER IV

EFFECTS OF THE BLUE EGG-SHELL GENE ON EGG QUALITY
AND OTHER ECONOMIC TRAITS IN THE CHICKEN [1]

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ABSTRACT

Araucana females homozygous dominant for the blue egg-shell allele (O) were mated to homozygous recessive (oo) Shaver Starcross "288" males to produce F1 hybrids heterozygous at the blue egg-shell locus. F1 females were backcrossed to Shaver males producing full-sib sisters half of which were blue egg layers and half white egg layers.

The white egg layers had a significantly higher percent egg production than the blue egg layers (82% vs. 79%). No significant differences (P > .05) between white and blue egg layers were found for shell quality, shell thickness, albumen weight, yolk weight, or yolk cholesterol.

INTRODUCTION

The blue egg-shell gene (O) is indigenous to the native South American breed of chicken known as Araucana and is inherited as an autosomal dominant gene (Punnett, 1933). The blue pigment permeates the entire shell (Punnett, 1933) and is thought to influence shell strength.

Relatively few studies have been conducted to evaluate the difference in performance and egg quality of blue egg layers and white egg layers. What studies have been conducted were not designed specifically to determine the effect of the blue egg-shell allele (O). Cunningham (1977) reported that shells of Araucana (blue) eggs were thicker than shells from either Leghorn (white) or Plymouth Rock (brown) eggs. Simmons and Somes (1978) indicated that Araucana eggs had larger yolks and less albumen for a given egg size than eggs from Leghorns; cholesterol content of the eggs was not measured. Anglin and Briles (1980) found that the amount of cholesterol per gram of yolk was similar among eggs from Araucana (AU), White Leghorn (WL), and Rhode Island Red (RIR) hens, although eggs from hens obtained by crosses of AU x RIR showed a significant reduction in the level of cholesterol. Reports in the popular literature concerning the low level of cholesterol in Araucana eggs (Hickman, 1974) have caused concern among scientists. The objective of this study was to determine the effects of the blue egg-shell gene on internal and external egg quality and on reproductive performance in hens with relatively similar genetic backgrounds but differing in genotype at the blue egg-shell locus.

MATERIALS AND METHODS

Araucana females homozygous dominant for the blue egg-shell allele (O) were mated to Shaver Starcross "288" males homozygous recessive for the blue egg-shell gene to produce heterozygous (Oo) F1 hybrids. Thirty-nine F1 females were backcrossed to Shaver males using artificial insemination with individually collected semen from eight males, thereby producing sisters half of which were blue-shelled egg layers (Oo) and half of which were layers of white-shelled eggs (oo). The chicks were wing-banded and sexed upon hatching and were beak-trimmed at 12 days of age. All females were brooded together. At 18 weeks of age, the hens were placed randomly in individual cages and received a standard laying ration containing 15% protein and 2,900 kcal/kg M.E. throughout the experiment. Caged pullets received 14 hr of illumination daily and were provided with water for eight 15-minute periods at 2-hr intervals during the light period. Data from 366 hens obtained from 4 hatches that survived to 40 weeks of age were analyzed in this experiment.

Growth was determined by measuring body weights at 20 and 40 weeks of age. Sexual maturity and percent hen-day egg production to 40 weeks of age were determined for each hen. Individual shell thickness was measured for first hatch hens from eggs collected during 2 days at 32 weeks of age using Instron measurement and Marius deformation methods described by Voisey and Hunt (1973). Individual egg weight, yolk weight, yolk color, albumen weight, shell weight, shell quality (specific gravity) and internal egg quality (Haugh unit) were determined for eggs collected during 3 days at 40 weeks of age. The average egg weight, specific gravity and Haugh unit for each hen were used in the statistical analyses. One yolk from each hen of hatch 1 was frozen and saved for cholesterol determination.

Frozen yolks were freeze-dried for 57 hr, weighed, and stored at -10C. Cholesterol was extracted by the method of

Washburn and Nix (1974). Cholesterol content was determined according to Zlatkis et al. (1953). Two optical density readings were averaged for unknown cholesterol samples from each egg yolk.

To determine the effect of the blue egg-shell gene on the measured variables, statistical analyses between white and blue egg layer siblings were made using analysis of variance on an average full-sib family basis with hatch as a block (Snedecor and Cochran, 1973). Data obtained for shell thickness were analyzed including day in the analysis of variance.

RESULTS AND DISCUSSION

No significant differences in body weight at 20 to 40 weeks of age and age at sexual maturity between white and blue egg layers were found (Table IV.1). Blue egg layers had significantly lower percent hen-day egg production compared with white egg layers. Somes et al. (1977) reported considerably lower egg production for Araucanas and speculated that this lowered egg production could be due to the presence of the blue egg-shell allele. Laying house livability to 40 weeks of age was similar for blue egg layers (98.9%) and white egg layers (97.8%).

There were no significant differences between white and blue egg layers for any of the egg characteristics measured (Table IV.2). Similar results were reported by Anglin and Briles (1980). Somes et al. (1977) found equal yolk sizes for white and blue eggs, although Araucana eggs had a significantly greater yolk/albumen ratio. Simmons and Somes (1978) reported that blue eggs had a 28% larger yolk, 8% less albumen, and 6% less shell weight than white eggs. Differences that have been observed between Araucana eggs and eggs from other breeds of domestic fowl in other studies cannot be attributed to the blue egg-shell gene alone since the gene was confounded with genetic background.

There was no significant difference between white and blue egg layers for cholesterol content of the yolk (Table IV.3). Similar results were reported by Anglin and Briles (1980) and by Cunningham (1977). However, Somes et al. (1977) found significantly greater yolk cholesterol concentration in blue eggs than in white eggs.

There were no significant differences between white and blue eggs for shell strength as indicated by Instron measures and Marius deformation (Table IV.4). Specific gravities for the two egg-shell colors were not significantly different from each other (Table IV.2). These findings are similar to those reported by Cunningham (1977).

Significant family effects were observed for body weight, age at sexual maturity, hen-day egg production, egg component weights and interior and exterior shell quality measures indicating the presence of genetic differences for these traits in the population of layers studied. Interestingly none of the yolk cholesterol measures varied among full-sib families, suggesting that a homeostatic level for yolk cholesterol had been reached in this population of birds.

In conclusion, the blue egg-shell allele (O) exerted little influence on growth and quantitative egg measures but did depress egg number. It follows that most differences reported for Araucana eggs versus other eggs of other breeds probably are due to the influence of the genetic background and not the blue egg-shell allele per se.

TABLE IV.1 Least squares means[1] for body weight, sexual maturity and percent egg production for white and blue egg layers

Trait	Egg-shell color phenotype	
	White (N=179)	Blue (N=187)
Body weight (g)		
20-weeks	1444[a]	1431[a]
40-weeks	1837[a]	1799[a]
Age at sexual maturity (days)	155[a]	157[a]
Hen-day egg production[2] (%)	82[a]	79[b]
Laying house livability (%)	97.8	98.9

[1]Means within a row with the same superscript are not significantly (P > .05) different.

[2]From sexual maturity to 280 days of age.

TABLE IV.2 Least squares means[1] for various egg characteristics
for white and blue egg layers at 40 weeks of age

Egg trait	Egg-shell color phenotype	
	White (N=179)	Blue (N=187)
Egg wt. (g)	57.6	57.8
Albumen wt. (g)	33.4	33.4
Yolk wt. (g)	16.3	16.3
Shell wt. (g)	7.9	8.1
Yolk color	9.9	10.0
Haugh unit	75.0	75.1
Specific gravity	1.0821	1.0820

[1]No significant differences (P > .05) across phenotypes were
observed.

TABLE IV.3 Least squares means[1] for yolk cholesterol content
for eggs of white and blue egg layers

	Egg-shell color phenotype	
Trait	White (N=62)	Blue (N=75)
Wet yolk wt. (g)	16.4	16.5
Dry yolk wt. (g)	8.3	8.4
Yolk moisture wt. (g)	8.1	8.1
Mg. Chol./g. wet yolk	12.2	12.1
Mg. Chol./g. dry yolk	24.7	24.6
Mg. Chol. in total yolk	205.5	205.6

[1]No significant differences (P > .05) across phenotypes were
observed.

TABLE IV.4 Least suqares means[1] for external egg quality for
eggs of white and blue egg layers

Trait	Egg-shell color phenotype	
	White (N=62)	Blue (N=75)
Instron (32 weeks)		
First day measurement	7.0	6.8
Second day measurement	6.9	6.7
Marius deformation (32 weeks)		
First day measurement	25.5	25.1
Second day measurement	25.1	25.8

[1]No significant differences (P > .05) across phenotypes were
observed.

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