GENETICS OF 120 DAY EGG PRODUCTION IN A SMALL POPULATION OF RING-NECKED PHEASANTS

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ABSTRACT

GENETICS OF 120 DAY EGG PRODUCTION IN A SMALL POPULATION OF RING-NECKED PHEASANTS

By

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A study to improve egg production in ring-necked pheasants (*Phasianus colchicus*) by application of poultry husbandry and breeding practices was initiated at Michigan State University in 1970 by Sheppard and Flegal (1973). Percent hen-housed egg production in excess of 50% over a 120 day production period in 1975 and 1976 was achieved by: 1) housing the pullets in individual cages, 2) starting the production period on January 1, thus avoiding hot weather, 3) using specially formulated rations during brooding, rearing, and production phases, 4) providing 14L:10D photoperiod during the first 90 days of the production period and 16L:8D during the last 30 days of the production period, and 5) using pullets ranging in age from 24 to 32 weeks.

Heritability estimates computed in 1973-76 were weighted by the inverse of the variance of the estimate to obtain a pooled estimate. Pooled estimates from the sire component were .065 for 90 day survivors egg production and .324 for

120 day survivors egg production. Standard errors of estimates were large; however, pooled estimates fall within the range reported in chickens and turkeys. Variation due to age differences at time of lighting appeared to be dependent on environmental conditions for each particular hatch and/or date of hatch.

In 1974 and 1975, female breeders were selected on the basis of individual records (selection pressure was 20% in 1974 and 27% in 1975), while male breeders were selected on the basis of dam's individual record (selection pressure was 20% in 1973 and 10% in 1974). Comparison of the selected population with a random-bred unselected population established in 1974 showed no improvement in 120 day egg production. Results suggest that family selection or progeny testing should be utilized in further attempts to improve 120 day egg production in ring-necked pheasants.

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INTRODUCTION

A decrease in the natural population of ring-necked pheasants (*Phasianus colchicus*) in recent years has resulted in an increase in artificial propagation of ring-necked pheasants. Growth in both the size and number of small game farms and the state supervised "put-and-take" program in Michigan, as originally suggested by Dr. Lloyd R. Champion, has resulted in the demand and need for ring-necked pheasants that are more efficient in egg production capabilities.

The purpose of this series of experiments conducted in cooperation with the Department of Natural Resources of the State of Michigan was to study the egg production potential of ring-necked pheasant pullets. Poultry husbandry practices such as housing the pheasant pullets in individual cages in a windowless house, the use of specifically formulated starter, grower, and breeder rations, and the supplementation of adequate color, intensity, and photoperiod of light to induce and maintain optimum egg production were applied to the flocks of ring-necked pheasants used in all studies reported herein. In addition, basic principles of population genetics and poultry breeding were applied in an effort to increase the egg production capabilities of ring-necked pheasant pullets.

LITERATURE REVIEW

Egg Production of Female Ring-Necked Pheasants

The egg production potential of female ring-necked pheasants, commonly referred to as "ring-necks", confined in flight pens during their natural breeding season has been the subject of several studies. The results of studies by Buss, Meyer, and Kabat (1948 and 1951) indicated that the egg laying season for female ring-neck pheasants in Wisconsin begins in April and extends into late June or early July. During this season of the year, numbers of eggs laid per female ranged from 15 eggs to 44 eggs, with an average of 42 eggs in one trial. In another trial, egg production ranged from 15 eggs to 76 eggs per female, with an average of 42 eggs. Westerskov (1956) reported an average of 67.3 eggs per female during one laying season for 37 yearling ring-neck pheasants confined at Ngongotha, New Zealand (Latitude 38° S). Westerskov also observed that under wild conditions yearling hens laid fewer eggs than older hens.

Labisky and Jackson (1966) housed nine female ring-neck pheasants in individual cages in an outdoor battery and measured egg production from April 10 to August 24.

Egg production ranged from 19 eggs to 107 eggs per female with an average of 70.6 eggs over the 137 day period.

Vandepopuliere, Kealy, Greene, and Williamson (1969) reported that egg production of female ring-necked pheasants measured from early spring through late summer was better in enclosed, fan-ventilated floor pens than in outdoor gravel pens or suspended colony cages. Results of that study also indicated that evaporative cooling showed no consistent advantage during the latter part of the production period and that by increasing the relative humidity during out-of-season periods increased egg production could be obtained.

The importance of the relationship between photoperiod and egg production in female ring-neck pheasants was first demonstrated by Bissonnette and Csech (1935). On January 15, after 30 days of three hours of night lighting, three ring-neck pheasant hens housed outside in cages, subjected to winter conditions, began to produce eggs. From January 15 to March 16, over 120 eggs were laid by the three hens. Smith, Hinkson, and Ousterhout (1968) subjected 28-week-old ring-neck pheasant pullets housed in 8 x 10 foot floor pens with eight hens and one male per pen to 14 hours of light per day starting on January 18. Pullets had an average hen day egg production of 35.5% and yearlings averaged 28.8% over the 112 day production period which began 17 days after lighting.

The effect of two different lighting regimes on egg production was investigated by Adams, Kahrs, and Deyoe (1968). Two groups of pullets approximately 24 weeks of age were housed at high population densities in colony cages and subjected to light on February 14. The group which received artificial light equivalent to natural daylength from February 14 to June 21 and 15 hours of light from June 21 to July 15 averaged 44 eggs per pullet as compared with an average of 57 eggs per pullet in the group which received a constant daylength of 15 hours from February 14 to July 15. These researchers suggested that the 13 more eggs produced by the birds in the constant daylength group resulted from higher egg production in the constant daylength group during the cooler months (March and April) of the trial. Egg production levels in this experiment were comparable with results obtained with similar stock housed at low population densities in outdoor flight pens.

The effects of temperature, relative humidity, and type of light on the egg production of ring-neck pheasant hens housed in colony cages was studied by Pekic (1967). Photoperiod was regulated to simulate natural daylength during the breeding season in Yugoslavia. Maximum egg production (121 eggs from December to June) was achieved by using incandescent light bulbs at 9 watts per square meter, 80% relative humidity, and 20° Centigrade room temperature.

Estimates of the Heritability of Egg Production in Chickens and Turkeys

Published estimates of the heritability of egg production in chickens include estimates for sundry breeds and strains and for different measures of egg production (typically survivors egg production spanning varying time intervals). A summary of heritability estimates published prior to 1953 as cited by King and Henderson (1954a) showed a range of heritability estimates for survivors egg production from .15 to .48 with an average of .31.

Estimates of the heritability of egg production in chickens calculated by using intrasire regression of daughters on dams reported by King and Henderson (1954a), Wyatt (1954), Wheat and Lush (1961), Kinney and Shoffner (1965), and Nordskog, Tolman, Casey, and Lin (1974) ranged from -.006 to .40.

Estimates of the heritability of egg production in chickens computed by the method of variance components have been reported by King and Henderson (1954a), Hays (1954), Wyatt (1954), Hill, Dickerson, and Kempster (1954), Jerome, Henderson, and King (1956), Hogsett and Nordskog (1956, 1958), Abplanalp (1956, 1957), Oliver, Bohren, and Anderson (1957), Fuchs and Kruger (1957), Yamada, Bohren and Crittenden (1958), Hicks (1958), Bray, King, and Anderson (1960), Wheat and Lush (1961), Goodman and Jaap (1961), King (1961), Manson and Abplanalp (1961), Friars, Bohren, and McKean (1962), Crittenden and

Bohren (1962), Jaap, Smith, and Goodman (1962), Quinn (1963), Siegel (1963), Van Vleck and Doolittle (1964), Kinney and Shoffner (1965), Amer (1967), Kinney, Lowe, Bohren, and Wilson (1968), Merritt (1968), and Marks, Lucas, and Godfrey (1968). As cited by the aforementioned researchers, estimates of heritability derived from the sire component, dam component, and sire plus dam component ranged from .01 to .28, .11 to .56, and .12 to .44, respectively.

Estimates of the heritability of egg production in turkeys have been reported by Wilson and Johnson (1946), Shaklee, Knox, and Marsden (1952), Blow and Glazener (1954), McCartney (1955), Kondra and Shoffner (1955), Blow, Stewart, and Glazener (1958), McCartney, Nestor, and Harvey (1968), Cook, Blow, Cockerham, and Glazener (1962), McCartney (1962), McCartney and Nestor (1965), Atkinson, Krueger, and Quisenberry (1967), McCartney, Nestor, and Harvey (1968), Mukherjee and Friars (1970), Nestor (1971, 1972), Nestor, Brown, and Weaver (1972), and Atkinson, Bradley, Krueger, and Quisenberry (1972). The heritability estimates reported range from -.65 to 1.51. This wide range is not surprising in the light of the small population size used in several of the studies. It should also be noted that the smaller range of heritability estimates reported for chickens is a direct result of larger population size.

METHODS AND MATERIALS

In 1970 a study was initiated by Sheppard and Flegal (1973) to determine the egg production potential in ring-necked pheasants. The base population was composed of females from three different strains which had been through one egg production cycle. Strain A was obtained from the State of Michigan Mason Game Farm, Mason, Michigan, and Strains B and C originated from the Bauer Game Farm, Lapeer, Michigan. The population used consisted of 75 hens from Strain A, 69 hens from Strain B, and 60 hens from Strain C. Individual egg production was recorded daily for a period of 304 days (November to August) for the hens of Strains A and B and over a 212 day period (January to July) for the Strain C hens. A summary of the results of this preliminary trial appears in Appendix A.

At the conclusion of the egg production trial in 1971, the low producing hens from Strains A and C and all hens from Strain B were culled. The remaining hens from Strains A and C were mated with males from Strains A and C, respectively. Pullets and male breeders used for study in 1973 consisted of progeny from these matings. In subsequent years, all breeding males were less than one year old and were mated to unrelated pullets where possible to minimize inbreeding. Breeding males used in 1974 were selected from pullets in the top 20% of the population studied in 1973 on the basis of 90 day egg production of their dams. All female chicks from five hatches in 1973 were saved and raised for use as replacement pullets for study in 1974. In 1975, a selected population consisting of daughters of the top 19% of the pullets tested in 1974 was established. Selection was based on 120 day egg production of dams. A control population was also established in 1975 which consisted of a random sample of pullets and male breeders hatched in 1974. Selected population pullets used for study in 1976 were progeny from matings between pullets from the top 27% of the 1975 selected population and male offspring from the top 10% of the pullets studied in 1974. Control population pullets studied in 1976 were progeny resulting from random mating between 1975 control birds.

The ring-necked pheasant pullets used in all egg production tests outlined herein were housed in individual wire cages which measured 7 x 14 x 12 inches (.178 x .356 x .305 m). All trials were conducted in a windowless house at the Michigan State University Poultry Science Research and Teaching Center (P.S.R.T.C.). A pheasant breeder ration (Appendix B) and water were provided *ad libitum* during all egg production trials. During the breeding season pedigreed eggs were set weekly in Jamesway

252 incubators. The eggs were incubated for three weeks at 99.5° F (37.3° C) and 60% relative humidity. After 21 days of incubation, the eggs were transferred to hatching units operated at 98.5° F (36.1° C) and 70% relative humidity. Upon hatching, the pheasant chicks were wing-banded and transported to brooding facilities at the P.S.R.T.C. A pheasant starter ration (Appendix C) and water were provided *ad libitum*. Heat and light were provided by three red, infra-red heat lamps. Heat lamps were added or removed as necessary to regulate room temperature. When the pheasant chicks were three to five weeks of age all heat lamps were removed and the birds were then raised in darkness to minimize cannibalism. A very slight amount of light, which was adequate to enable the chicks to eat and drink, entered the house through the air intake slots and exhaust fan enclosures. At six weeks of age the pheasant chicks were separated by sex, specked, and switched from pheasant starter to a pheasant grower ration (Appendix D). The birds received pheasant grower until time of lighting in all years except 1976 when they received a pheasant flight ration (Appendix E) from 12 weeks of age until time of lighting.

During the 1973 test period ring-necked pheasant pullets which ranged in age from 24 to 35 weeks were removed from darkened pens and housed in individual cages mounted in battery frames. The pullets at the time of caging received 14 hours of light (6 a.m. to 8 p.m.) per day as provided by 60 watt frosted incandescent light bulbs. At the conclusion of a two week pre-lighting period, daily individual egg production and mortality were recorded for a 90 day (April 1 to June 30) period. Room temperature varied from 55° F to 80° F (13° C to 27° C). Higher room temperatures occurred during the latter portion of the production period. The pullets were divided into ten full and half-sib family groups which ranged in size from 11 to 15 individuals. A set of five pullets within each group was removed from their cages in the morning and placed in a 10 x 16 foot (3.048 x 4.877 m) single male mating pen. Whenever possible an unrelated male was used. In the late afternoon each set of pullets was returned to their cages. Sets of pullets within each family were rotated so that each pullet in each group spent one day per week on the floor of the breeding pen. All eggs from the first eight settings which failed to hatch were broken out and examined macroscopically to determine fertility.

In the 1974 trial, ring-necked pheasant pullets which ranged in age from 36 to 40 weeks were transferred from darkened floor pens to individual cages mounted on the wall within the single male mating pens, each of which measured 10 x 16 feet (3.048 x 4.877 m). The pullets were divided into six groups of full and half-sib families and assigned to a breeding pen with an unrelated male where possible. In this trial each group was divided into five sets of three pullets. Each pullet of a set was placed on the floor in the morning and returned to her cage late in the afternoon. Sets of females were rotated so that each pullet was available for natural mating once each week. On March 1 the pullets were exposed to eight hours of light per day with an increase of one and one-half hours of light per week until 14 hours of light per day (6 a.m. to 8 p.m.) was provided. One 60 watt frosted incandescent light bulb per pen supplied illumination. Duration of lighting period was increased to 16 hours (6 a.m. to 10 p.m.) in mid-June. At the conclusion of a two week pre-lighting period, daily individual egg production and mortality were recorded for a 120 day (March 15 to mid-July) period. Room temperature during this trial ranged from 50° F to 85° F (10° C to 30° C) with a gradual increase in room temperature as the trial progressed. Fertility and hatchability were monitored from hatches 7 through 9.

In 1975, ring-necked pheasant pullets which ranged in age from 24 to 32 weeks were moved from darkened floor pens to individual cages mounted on the wall inside a 10 x 16 feet (3.048 x 4.877 m) breeding pen. The pullets from the selected population were divided into seven full and half-sib family groups. The pullets from the control population were randomly assigned to cages in three breeding pens and were mated to control breeding males that were rotated periodically from pen to pen. With the exception that sets of pullets were placed on the floor late in the afternoon and returned to their cages early the following morning, breeding methods were the same as in 1974. At the conclusion of a two week pre-lighting period, daily individual egg production and mortality were recorded for a 120 day (February 1 to May 31) period. Pullets in this trial received 14 hours of light per day (6 a.m. to 8 p.m.) from January 15 to May 1. Sixteen hours of light per day (6 a.m. to 10 p.m.) were provided from May 1 to May 31. The source of illumination during this test consisted of one 60 watt frosted incandescent light bulb per breeding pen. Room temperature during this trial ranged from 46° F to 84° F (9° C to 30° C). All temperatures above 70° F (21° C) occurred in May. All eggs from the first four settings which failed to hatch were broken out for a macroscopic determination of fertility.

In 1976, ring-necked pheasant pullets, which ranged in age from 24 to 32 weeks, were transferred from darkened floor pens to individual cages mounted on the wall inside a 10 x 16 feet (3.048 x 4.877 m) breeding pen. Pullets in this trial received 14 hours of light per day (6 a.m. to 8 p.m.) from December 15 to March 31. From April 1 to April 30, 16 hours of light per day (6 a.m. to 10 p.m.) were provided. At the conclusion of a two week pre-lighting period, daily individual egg production and mortality were recorded for a 120 day period (January 1 to April 30). During this trial, illumination was provided by one 60 watt incandescent light bulb per breeding pen. Room temperature ranged from 50° F to 74° F (10° C to 22° C). All temperatures in excess of 64° F (18° C) occurred in April.

RESULTS AND DISCUSSION

Egg Production

Table A-2 (Appendix A) from the preliminary egg production test conducted by Flegal and Sheppard in 1970 shows that ring-necked pheasant hens reach peak production during the second month of lay and produced most of their eggs during the first three months of the egg production test period. Based on these results, egg production was studied for a 90 day period in the 1973 egg production test. Tables A-1 and A-3 from Appendix A verify that hens from Strains A and C produced eggs at a higher rate than hens from Strain B. At the conclusion of this egg production trial, hens from Strain B were culled and hens from Strains A and C were saved for breeding purposes.

Since all birds used in the 1970 trial had already been through one egg production cycle when egg production records were kept, the 44 top producing pullets used in the 1973 trial were saved so that records for a second egg production cycle could be compared with the records obtained during the first egg production cycle.

The average number of eggs produced per female for a 90 day period in the first laying cycle was 56.2 eggs.

The average number of eggs produced per female for a 90 day period in the second laying cycle was 54.1, an average decrease of 2.1 eggs per female over the 90 day period. It is suggested, therefore, that better egg production results can be obtained by using pullets instead of hens. Smith et al. (1968) reported that hen ring-necked pheasants produce fewer eggs than ring-necked pheasant pullets housed in floor pens at low density. A similar trend has also been reported in chickens by numerous researchers. Hutt (1949) and Lerner (1950) attribute this yearly decline in egg production level to senescence.

Egg production of ring-necked pheasant pullets for 90 and 120 day periods from trials conducted in 1973, 1974, 1975, and 1976 was calculated on a hen-housed basis for the purpose of comparison with results from the 1970-71 trial. The results of this comparison are shown in Table 1. Hen-housed egg production for the first 90 days increased 17.4% from 1970-71 to 1975. The largest increase in egg production occurred between the 1970-71 and 1973 tests. This increase could be attributed to the following factors:

1. In 1973, pullets were used instead of hens.
2. The turkey breeder ration (Appendix F) used in 1970 was replaced by pheasant breeder ration (Appendix B) in 1973.
3. All individuals in Strain B and poor layers in Strains A and C were culled due to poor production records.

Table 1. Comparison of hen-housed egg production for all years

Year	No. Birds Housed	Hen-Housed % Egg Production for First 90 Days	Hen-Housed % Egg Production for First 120 Days
1970-71	204	36.6	32.9
1973	112	45.4	---
1974	91	51.3	46.4
1975[a]	120	52.9	50.2
1976[a]	140	54.0	52.7

[a]Represent selected and unselected populations combined.

4. Improvements in management procedures were initiated during the brooding, rearing, and production periods.

Small yearly increases in egg production over a 90 and 120 day period are reflected in Table 1. The start of the test period for measuring egg production was moved progressively toward the beginning of the calendar year between 1973 and 1976. As a result, the onset of warmer room temperature moved progressively toward the end of the egg production test period. This trend could be responsible for the yearly increases in egg production between 1973 and 1976 since a decline in egg production of ring-necked pheasant pullets in response to warmer temperatures was noted in this series of experiments and in the work of Adams et al. (1968). It is therefore suggested that a 120 day egg production test period in a climate comparable to Michigan should begin in late fall no later than January 1 with room temperature regulated between 50° F and 65° F (10° C - 18° C).

The percent hen-housed egg production of ring-necked pheasant pullets housed in individual cages in 1976 from this study exceeded egg production of ring-necked pheasant females housed in outdoor flight pens in Wisconsin (Buss et al., 1948 and 1951) and ring-necked pheasant females housed in floor pens at low density (Smith et al., 1968). The average number of eggs laid per pullet housed in colony cages at high density over a period of five months (Adams et al., 1968) was comparable to production levels achieved over a period of four months during 1974, 1975, and 1976 in this study. The average number of eggs produced per female in this study was less than the average number of eggs per female housed in: 1) an outdoor flight pen in New Zealand (Westerskov, 1956), 2) individual cages in an outdoor battery (Labisky and Jackson, 1966), and 3) "...wire cases of several storeys..." (Pekic, 1967). However, the egg production test period in each of these three studies exceeded 120 days. On the basis of an equivalent egg production test period, the egg production level in this study was comparable with Westerskov (1956) and Labisky and Jackson (1966), but was still considerably less than Pekic (1967).

Hen-housed percent egg production from 1970-71, 1973, 1974, 1975, and 1976 of ring-necked pheasant pullets and hens was also studied on a monthly basis. Production curves for all egg production trials are presented in Figure 1. Ring-necked pheasant pullets used for study in 1973, 1975, and 1976 all received the same photoperiod (14L:10D during pre-lighting and during the first three months of their production period and 16L:8D during the fourth month of the production period) and had similar ranges in age at the start of the pre-lighting period (see Table 1). Egg production curves for ring-necked pheasant pullets used for study in 1973, 1975, and 1976 reached peak production during the second month of lay with fairly consistent monthly decrease in egg production

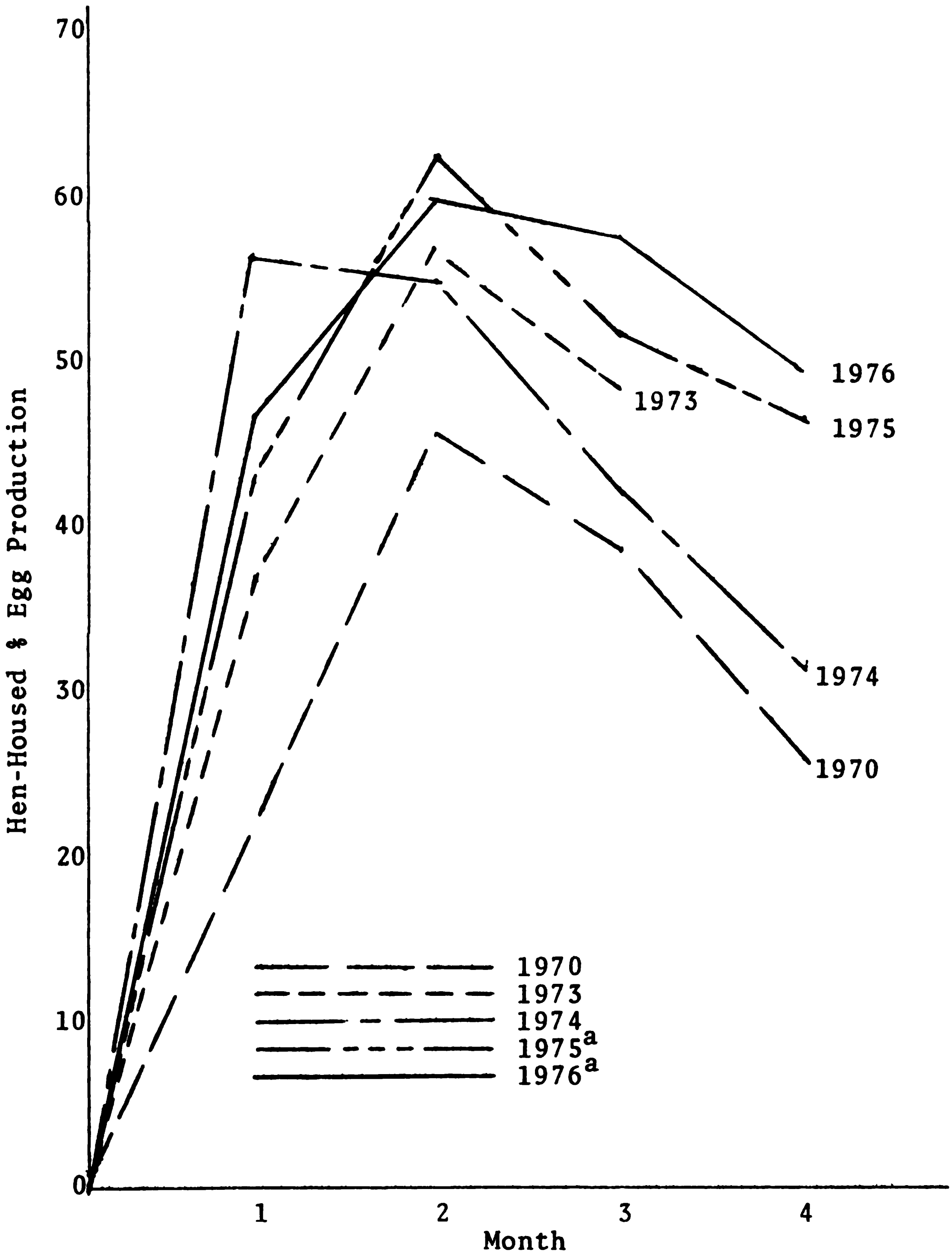

Figure 1. Hen-housed egg production by months.

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[a]Represents selected and unselected populations combined.

during the last two months of the trial. However, pullets studied in 1974 were older at time of lighting (see Table 1) than pullets studied in 1973, 1975, and 1976 and received a different photoperiod (8L:16D with a weekly increase of one and one-half hours until 14L:10D was reached and an additional increase to 16L:8D during the fourth month of the test period). Figure 1 indicates that pullets in the 1974 egg production test reached peak production during the first month of lay with a steady monthly decrease in egg production during the last three months of the test period. This shift in peak production from the second month of lay to the first month of lay could be attributable to differences in range of age of pullets at the start of the production period, differences in lighting regime, or an interaction of these two factors. Upon comparison of percent hen-housed egg production over 90 and 120 day periods in 1974, 1975, and 1976 from Table 1, there seems to be no particular advantage in using older pullets in conjunction with the lighting program used in 1974 that cannot be realized by starting the egg production trial on January 1.

In order to estimate the age at which ring-necked pheasant pullets are sexually mature, total egg production during a 90 day test period was expressed as a function of age at the start of the two week pre-lighting period. The average number of eggs produced by ring-necked pheasant pullets, which ranged in age from 24 to 35 weeks, studied in 1973, 1975, and 1976 and 1973-1976, are grouped by age at time of pre-lighting and are shown in Table 2. Data shown in Table 2 indicate that ring-necked pheasant pullets pre-lit as young as 24 weeks of age are capable of satisfactory levels of egg production.

In order to determine the extent to which age alone affects egg production, 90 day egg production was regressed on age at time of pre-lighting. A summary of the regression coefficients of 90 day egg production of surviving pullets on age at time of pre-lighting and standard errors of these coefficients is presented in Table 3. In 1974 and 1975, age at time of lighting had no significant effect on egg production levels; however, age exerted a highly significant effect on rate of egg production in 1973 and 1976. In 1973, the youngest pullets produced eggs at a higher rate, while in 1976 the oldest pullets produced eggs at a higher rate. This apparent lack of consistency in the manner and extent to which age differences at the time of lighting influence egg production could possibly be attributed to environmental conditions during incubation, brooding, and rearing periods peculiar to each hatch within a given year or date of hatch.

Since the egg production potential of individuals that do not survive to the end of a 90 or 120 day egg production test period cannot be estimated accurately, egg production of survivors of 90 and 120 day test periods in 1973, 1974, 1975, and 1976 is presented in Table 4. Percent egg

Table 2. Average number of eggs produced per pullet when grouped according to age at time of pre-lighting

	Age in Weeks											
Year	24	25	26	27	28	29	30	31	32	33	34	35
1973	52.3	51.1	45.4	48.1	33.2	50.6	30.3	33.5	41.8	0.0	36.5	39.8
1975	27.8	50.0	51.7	43.8	55.7	52.1	36.4	44.1	37.7	---	---	---
1976	33.8	43.0	48.3	45.9	---	58.7	56.8	42.8	63.1	---	---	---
1973-1976	38.4	46.1	48.8	46.1	39.8	53.9	43.7	41.8	52.0	0.0	36.5	39.8

Table 3. Regression of 90 day egg production of survivors on age of pullet

Year	Range of Age in Weeks	Regression Coefficient ± S.E.
1973	24-35	-1.746 ± .596[a]
1974	36-40	-2.391 ± 1.966
1975	24-32	-1.016 ± .946
1976	24-32	5.104 ± .716[a]

[a]Highly significant (P<0.01).

Table 4. Egg production of survivors

Year	Number of Survivors	% Egg Production First 90 Days	% Egg Production First 120 Days
1973	109	46.5	---
1974	73	59.5	53.8
1975[a]	119	52.7	50.1
1976[a]	133	55.6	54.7

[a]Represents selected and unselected populations combined.

production of survivors for a 90 day test period was highest in 1974, while percent egg production for a 120 day test period was highest in 1976. Percent mortality over the 90 day production period in 1973 and over the 120 day egg production period in 1974, 1975, and 1976 was 2.7, 19.8, 0.8, and 5.0, respectively. Postmortem examination of pullets that died during the 1974 trial revealed that disease was not responsible for the increase in mortality noted in 1974. The primary cause of mortality in all egg production tests was death from physical injuries presumably incurred while trying to escape the confines of individual caging. Since the pullets used for study in 1974 were older than pullets used in 1973 and 1975, it seems reasonable to conclude that older pullets do not adapt as well to a caged environment. Approximately two-thirds of the mortality in 1974 occurred during the first month of the test period among birds that had not produced any eggs, thus increasing percent egg production of survivors in 1974. About 10% of all birds housed in each trial failed to produce any eggs; however, in 1973, 1975, and 1976 nearly all of these non-layers survived.

Heritability Estimates

In order to produce enough replacement ring-necked pheasant pullets for continued study, multiple hatches were necessary. As a direct consequence of many successive hatches, a hatch effect was included in the statistical model used to estimate variance components necessary to compute heritability (h^2) estimates. Variance components used to estimate heritability were derived from the "hierarchial nested model" of King and Henderson (1954b):

$$Y_{hijk} = u + a_h + S_{hi} + d_{hij} + e_{hijk}$$

where Y_{hijk} represents egg production of the kth progeny from the jth dam mated to the ith sire within the hth hatch. Since a hatch effect was included in the statistical model, all heritability estimates represent estimates computed on a within-hatch basis. Heritability was estimated from the sires' variance component (h^2_S), from the dams' variance component (h^2_D), and from combined sire and dam components (h^2_{S+D}). The estimate from the sires' component contains only additive genetic variance and is an unbiased estimator. Estimates from the dams' component and the combined components are biased upward since the estimate from the dams' component contains all of the dominance variance and the combined estimate contains one-half of the dominance variance in addition to additive genetic variance. Approximate standard errors of all three heritability estimates were also computed since the estimates were derived from a very small population.

Individual egg production records of survivors of the 1973, 1974, 1975, and 1976 experiments were used to estimate the heritability of 90 and 120 day egg production. In addition, a pooled estimate was computed for each of the three estimates by weighting each yearly estimate by the inverse of the variance of that particular estimate. Heritability estimates and standard errors of 90 day egg production of survivors are shown in Table 5. The standard errors of the heritability estimates presented in Table 5 are extremely large due to the very small size of the population from which the estimates were computed. Consequently, extreme caution should be exercised in assessing the reliability of individual estimates, particularly estimates of h^2_D. However, the pooled estimates shown in Table 5 for h^2_S and h^2_{S+D} based on a four year study should provide reasonable approximations of actual values. The estimate of h^2_S given in Table 5 falls within the range of estimates for chickens and turkeys and indicates that the heritability of 90 day egg production in ring-necked pheasant pullets is very small. Two assumptions which assure that heritability estimates from variance components are unbiased have been violated in this experiment in that sires and dams were selected in 1974 and 1975 and some sires and dams in all years were related and inbred. However, in the light of the magnitude of standard errors associated with estimates from all trials, potential sources of bias from these sources would have little effect on reliability of estimates.

Table 5. Heritability estimates and standard errors of 90 day egg production of survivors

Year	h^2_S	h^2_D	h^2_{S+D}
1973	.113 ± .529	.013 ± 1.201	.063 ± .603
1974	.441 ± .667	.816 ± 1.069	.628 ± .448
1975	.079 ± .536	.454 ± 1.047	.267 ± .463
1976	-1.013 ± 1.014	2.113 ± 1.242	.550 ± .330
Pooled	.065	.801	.445

$$h^2_S = \frac{4S}{S+D+E}$$

$$h^2_D = \frac{4D}{S+D+E}$$

$$h^2_{S+D} = \frac{2(S+D)}{S+D+E}$$

Where: S = estimate of variance component of sires

D = estimate of variance component of dams

E = estimate of variance component of error

Estimates of the heritability of 120 day egg production of survivors and standard errors of the estimates are presented in Table 6. The estimates shown in Table 6 also possess extremely large standard errors but still fall within the range reported for turkeys. The pooled estimate of h^2_S in Table 6 is larger than the pooled estimate of h^2_S in Table 5, which suggests that the heritability of 120 day egg production of survivors is higher than the heritability of 90 day survivors egg production.

An additional unbiased estimate of the heritability of 90 and 120 day survivors egg production was computed using the repeated parent technique of intrasire regression of daughters egg production on dams egg production. In addition, standard errors of estimates and a pooled estimate, which was derived by weighting each estimate by the inverse of the variance of that estimate, were also calculated. Heritability estimates and standard errors of 90 and 120 day egg production of survivors using intrasire regression are presented in Table 7. Standard errors of estimates shown in Table 7 are extremely large and of the same order of the standard errors of h^2_S given in Tables 5 and 6. Once again, the reliability of estimates derived from a very small population should be assessed with great caution. The pooled estimate of h^2 shown in Table 7 for 90 day egg production is much larger than the value of h^2_S given in Table 5 while the estimate of h^2 for 120 day egg production presented in Table 7 is

Table 6. Heritability estimates and standard errors of 120 day egg production of survivors

Year	h^2_S	h^2_D	h^2_{S+D}
1974	.441 $\pm$ .679	.816 $\pm$ 1.016	.628 $\pm$ .412
1975	.563 $\pm$ .519	-.297 $\pm$ 1.050	.266 $\pm$ .536
1976	-.798 $\pm$ .993	1.897 $\pm$ 1.203	.550 $\pm$ .334
Pooled	.324	.799	.561

Table 7. Heritability of 90 and 120 day egg production of survivors using intrasire regression

Year	$h^2 \pm$ S.E. 90 Day	120 Day
1974	.609 ± .516	---
1975	-.289 ± .674	-.215 ± .621
1976	3.770 ± 1.260	3.130 ± 1.461
Pooled	.611	.297

slightly smaller than the estimate of h^2_S given in Table 6. The lack of agreement of heritability estimates from variance components and intrasire regression is not surprising when the size of standard errors from both methods is taken into consideration.

Effects of Selection and Inbreeding on Egg Production

One of the major goals of this study was to increase the egg production level of ring-necked pheasants using a selection program. At the conclusion of the 1974 egg production trial, potential breeders were selected on the basis of individual 120 day egg production records. Since no selection, with the exception of some culling done in 1970, had been done in the population under study, it seemed that selection on this basis would initially be effective in improving egg production level in the flock under study. Consequently, dams were selected from the top 20% based on 120 day egg production of the pullets studied in 1974 and mated to sires which were offspring from the top 20% of the pullets studied in 1973 based on 90 day egg production records. In addition, a random sample of male and female chicks which were hatched in 1974 was saved for use as an unselected population for purposes of comparison. Male and female chicks in the unselected population were sired by the same males as chicks in the selected population, so that any differences between selected and unselected pullets would be due to genetic differences between dams. A summary of 120 day egg production of selected and unselected pullets studied in 1975 appears in Table 8. A comparison between the 120 day egg production averages of the selected and unselected populations indicates that selection of female breeders on the basis of individual records was ineffective in increasing 120 day egg production. At the conclusion of this trial it appeared that family selection instead of mass selection would be more effective in improving egg production. However, an insufficient number of progeny was available from the top producing families due to very poor fertility from certain males, and breeders were again selected on the basis of individual records. Dams were selected from the top 27% of the pullets studied in 1974 based on 120 day egg production and sires were offspring from the top 10% of the dams studied in 1974 based on 120 day egg production. The unselected population was maintained by saving chicks from random mated sires and dams from the unselected population. Average egg production over a 120 day period for the selected and unselected populations in 1976 is presented in Table 8. A comparison between average egg production of the selected and unselected populations in 1976 indicates once again that mass selection was not effective in increasing egg production over a 120 day period.

The lack of improvement of the selected population when compared with the unselected population indicates

Table 8. Average number of eggs laid over a 120 day period

Year	Number of Selected Birds	Selected Population Average Production	Number of Unselected Birds	Unselected Population Average Production
1975	81	59.3	39	62.3
1976	100	59.7	40	72.1

that the heritability of 120 day egg production is much lower than was anticipated at the start of the selection program. Estimates of realized heritability, which were computed by dividing the average improvement of the selected population over the unselected population by the average selection differential, were negative, but again suffer from lack of reliability due to very small population size. It therefore seems reasonable to conclude that the heritability of short term egg production in ring-necked pheasants is near zero and perhaps close to the pooled estimate of h^2_S shown in Table 5. If the heritability of short term egg production is indeed this small (.065), family selection and/or progeny testing should be utilized instead of mass selection in further attempts to improve egg production through selection. However, as cited by Hutt (1949), progeny testing on a small scale (six single male breeding pens) has led to discouraging results in terms of improved egg production in chickens. Therefore, if further attempts are made to improve egg production using family selection and progeny testing, population size should be increased substantially to insure improvement. In addition, accuracy of selection may possibly improve if the number of hatches can be reduced. Perhaps an alternative to further attempts at increasing egg production through a selection program would be further experimentation with different lighting regimes or other improvements in environmental conditions conducive to optimum egg production.

The apparent superiority in egg production of the unselected population over the selected population, particularly in 1976, was quite surprising and deserves more careful scrutiny. The most apparent difference between the two populations in 1976 was that all of the pullets in the unselected population produced eggs, while only 88% of the pullets in the selected population produced eggs. This factor accounts for about one-half of the difference in egg number between the two populations in 1976. Perhaps individuals selected as breeders laid well because they adapted to the individual caging environment rather than because they possessed a genotype for high egg production. Consequently, very little superior egg producing ability was transmitted to their offspring. If the number of non-layers could be reduced by management techniques, improved egg production results may possibly be obtained.

Since 50% of the individuals in the 1976 unselected population were descendants of top layers in 1973 and 1974, the question also arises as to how adequately the unselected population served as a control group. The mean 120 day egg production for the unselected daughters and granddaughters of top layers in 1973 and 1974 was 73.0 eggs whereas the mean 120 day egg production of the remainder of unselected pullets was 71.2 eggs. It appears, therefore, that the superior egg production capabilities of the unselected population was not due to past breeding history of the individuals in that population. Perhaps the ideal control population to determine the effect of selection on 120 day egg production level would be comprised of stock originating from eggs collected from the wild. Then hatch the eggs and brood and rear these chicks under the same conditions as the selected stock.

Since complete pedigree information was compiled during all trials, the effect of inbreeding on egg production could be assessed. The range of percent inbreeding, average percent inbreeding, regression coefficients of number of eggs produced by survivors in 90 days on percent inbreeding, and standard errors of the coefficients of regression are presented in Table 9 for 1973-1976. An increase in percent inbreeding resulted in a non-significant decrease in egg numbers in 1973 and 1975. In 1974 and 1976, an increase in percent inbreeding resulted in a non-significant increase in egg number. The limited data available suggest that inbreeding at the levels present in this study did not affect survivors egg production.

Fertility and Hatchability Data

Fertility and hatchability data for the first eight hatches of eggs set in 1973 are presented in Table 10. The percentage of eggs set which were fertile increased

Table 9. Range in percent inbreeding, average percent inbreeding, and regression of number of eggs laid by survivors on percent inbreeding

Year	Range in Inbreeding %	Average Inbreeding %	Regression Coefficient $\pm$ S.E.
1973	0 - 12.5	3.84	-.603 $\pm$ .416
1974	0 - 25.0	6.08	.695 $\pm$ .362
1975[a]	0 - 18.75	6.96	-.141 $\pm$ .541
1976	3.52 - 10.16	6.74	.718 $\pm$ 1.437

[a]Represents selected and unselected populations combined.

Table 10. Fertility and hatchability data from 1973

Hatch Number	Eggs Set, Number	Fertile Eggs, Number	Chicks Hatched, Number	Fertile Eggs, %	Hatchability, %	Hatch, %
1	227	48	37	21.1	77.1	16.3
2	572	105	72	18.4	68.6	12.6
3	494	171	120	34.6	70.2	24.3
4	516	228	154	44.2	67.5	29.8
5	488	213	161	43.4	75.6	33.0
6	489	270	172	55.2	63.7	35.2
7	470	248	160	52.8	64.5	34.0
8	426	226	149	53.1	65.9	35.0
Average	---	---	---	41.0	67.9	27.8

during the first six hatches before reaching a plateau. The gradual increase observed during the first six hatches suggests that when floor-housed males are mated to cage-housed breeder females, a period of acclimation is necessary to achieve a level of 50% fertility. Hatchability of fertile eggs in 1973 declined during the last three hatches. However, the corresponding increase in fertility negated this effect so that no change in percentage of eggs set that hatched occurred.

In Table 11, fertility and hatchability data for three hatches near the end of the hatching season in 1974 are presented. Percentage of fertile eggs had not yet reached a plateau in 1974, but no difference existed between average percentage of fertile eggs from hatches 6-8 in 1973 (53.7%) and average percentage of fertile eggs from hatches 7-9 (53.5%) in 1974. It seems reasonable to assume, therefore, that putting three different females on the floor each day five times per week has no advantage over dropping five females three times per week for mating. Percentage of fertile eggs which hatched when averaged over similar hatches was higher in 1974 (72.0%) than in 1973 (64.6%). Since handling, storage, and incubation procedures were the same in 1973 and 1974, no difference would be expected. The percentage of all eggs set that hatched from hatches 6-8 in 1973 and hatches 7-9 in 1974 was comparable with the exception of hatch 9 in 1974,

Table 11. Fertility and hatchability data from 1974

Hatch Number	Eggs Set, Number	Fertile Eggs, Number	Chicks Hatched, Number	Fertile Eggs, %	Hatchability, %	Hatch, %
7	174	74	58	42.5	78.4	33.3
8	328	174	116	53.0	66.7	35.4
9	193	124	94	64.0	75.8	48.7
Average	---	---	---	53.5	72.0	38.6

which was superior to all others. This is not surprising since both fertility and hatchability were highest in this particular hatch.

Fertility and hatchability data for the first four hatches of eggs set in 1975 are presented in Table 12. The percentage of eggs set which were fertile from the first four hatches in 1975 was lower than the corresponding percentage for the first four hatches in 1973. Since four breeder males out of ten produced no fertile eggs in the first three hatches in 1975 and three males out of ten produced no fertile eggs in the fourth hatch in 1975, it is not surprising that fertility from the first four hatches in 1975 was so low. In order for a selection program to be effective, offspring are necessary from numerous specific matings. Therefore, a major stumbling block toward improving performance for a specific trait is encountered when some 40 to 60% of all potential breeding-age males produce no offspring. Another consequence is that the duration of the hatching season must be extended to produce an adequate number of replacement pullets from desired individuals. The increase in number of hatches would then introduce an undesirable source of variation with which to contend when the results are interpreted by reason of an additional variable in an already complex statistical model.

A comparison of hatchability averaged over the first four hatches in 1973 and 1975 indicated that average

Table 12. Fertility and hatchability data from 1975

Hatch Number	Eggs Set, Number	Fertile Eggs, Number	Chicks Hatched, Number	Fertile Eggs, %	Hatchability, %	Hatch, %
1	354	60	48	16.9	80.0	13.6
2	540	112	59	20.7	52.7	10.9
3	581	144	81	24.8	56.2	13.9
4	541	188	95	34.8	50.5	17.6
Average	---	---	---	30.5	69.4	14.0

percent hatchability in 1975 (56.2%) was lower than in 1973 (69.4%). Again, no difference in hatchability between the first four hatches in 1973 and 1975 was expected, since handling, storage, and incubation procedures were the same for both years. Since the average fertility for the first four hatches in 1975 (25.0%) was lower than in 1973 (30.5%), and the average hatchability for the first four hatches in 1975 was lower in 1975 (56.2%) than in 1973 (69.4%), it therefore follows that percent of all eggs set which hatched when averaged over the first four hatches would be lower in 1975 (14.0%) than in 1973 (21.2%).

The percent of fertile eggs in this study, using floor-housed breeding males and cage-housed pullets, is much lower than results from a study using ten females and one male in a high density cage system (Adams et al., 1968) and are also lower than results of a study (Smith et al., 1968) where eight hens and one male were placed in an 8 x 10 feet floor breeding pen. However, in a genetic study in which complete pedigrees are essential, neither of the above-mentioned breeding methods could be utilized unless females are trap-nested or housed in single cages. It appears that the best alternative to cage-housed females and floor-housed males, which would at the same time provide complete pedigree records and accurate individual egg production data, is a program of artificial insemination which would allow multiple insemination of hens with semen collected from one male breeder.

CONCLUSION

From the results of a four year study of the egg production of a small flock of ring-necked pheasant pullets, the following conclusions appear to be warranted:

1. When female ring-necked pheasants are housed in individual cages, pullets produce more eggs than hens that have already been through one egg production cycle.

2. Egg production in excess of 50% on a hen-housed basis over a 120 day period was achieved using the following management practices:

   a. House the pullets in individual cages.

   b. Begin the egg production test period in late fall or early winter, thus avoiding hot weather.

   c. Using specially formulated pheasant rations during the brooding, rearing, and egg production phases.

   d. Provide 14 hours of light per day to initiate and maintain egg production during the first 90 days as provided by one 60 watt frosted incandescent light bulb per 10 x 16 feet (3.048 x 4.877 m) breeding pen.

3. Ring-necked pheasant pullets are ready to be prelit at 24 weeks of age.

4. The effect of age of pullet at the start of egg production varies, i.e., it was not consistent from year

to year. Rather, it appears that the age effect is dependent on environmental conditions, and/or quite possibly the date of hatch effect.

5. Derived estimates for the heritability of survivors egg production for 90 and 120 days fall within the range of estimates reported for chickens and turkeys. These data indicate, therefore, that the same type of selection programs used for chickens and turkeys to improve egg production levels are applicable to ring-necked pheasants. In other words, selection of breeders solely on the basis of individual egg production records was not effective in increasing 120 day egg production. It is suggested that family selection, progeny testing, or both, should be used to increase egg production.

6. Inbreeding, at the levels present in this series of experiments, had no effect on number of eggs produced.

7. A breeding system utilizing cage-housed females and floor-housed males resulted in low fertility and necessitated multiple hatches that may have impeded the progress of the selection program. It is therefore suggested that artificial insemination should be used in any further pedigree work.

APPENDICES

APPENDIX A

TABLES

Table A-1. Egg production for female pheasants of Strains A, B, and C in 1970-71

Strain	Number of Birds	Number of Days	Average No. of Eggs Per Bird Housed	Hen-Housed Egg Production %
A	75	304	59.1	19.4
B	69	304	33.0	10.9
C	60	212	60.8	28.7

Table A-2. Hen-housed percent egg production by months in 1970-71

Strain	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
A	37.4	48.7	39.5	23.4	17.8	8.9	6.7	4.8	3.5	4.0
B	21.2	34.5	23.8	15.7	8.3	2.7	1.4	1.3	0	0
C	8.1	55.1	52.5	34.6	20.0	17.3	15.6	---	---	---

Table A-3. Egg production for Strains A, B, and C over a seven month period in 1970-71

Strain	Number of Birds	Average No. of Eggs Per Bird Housed	Hen-Housed Egg Production %
A	75	55.4	26.1
B	69	32.7	15.4
C	60	60.8	28.7

APPENDIX B

PHEASANT BREEDER

Ingredient	Number of Pounds
Corn	1065
Soybean meal, 44%	300
Oats	150
Wheat middlings	150
Alfalfa, 17%	60
Fish meal, 60%	50
Meat and bone meal, 50%	60
Whey, dried	40
Salt	5
Dicalcium phosphate	30
Limestone	75
Premix[a]	15
	2000

<u>Calculated Analysis</u>

Crude protein, %	18.00
Fat, %	3.44
Fiber, %	4.65
Calcium, %	2.40
Phosphorus, available %	.68
M.E., Cal/lb.	1225

[a]Premix 5004, available from Dawes.

APPENDIX C

PHEASANT STARTER

Ingredient	Number of Pounds
Corn	927
Soybean meal, 49%	788
Alfalfa, 17%	60
Fish meal, 60%	50
Meat and bone meal, 50%	60
Whey, dried	40
Salt	5
Dicalcium phosphate	30
Limestone	25
Premix[a]	15
	2000

Calculated Analysis

Crude protein, %	28.00
Fat, %	2.61
Fiber, %	3.32
Calcium, %	1.47
Phosphorus, available %	.70
M.E., Cal/lb.	1241

[a]Premix 5004, available from Dawes.

APPENDIX D

PHEASANT GROWER

Ingredient	Number of Pounds
Corn	1090
Soybean meal, 49%	510
Wheat middlings	150
Alfalfa, 17%	60
Fish meal, 60%	50
Meat and bone meal, 50%	60
Salt	5
Dicalcium phosphate	30
Limestone	30
Premix[a]	15
	2000

<u>Calculated Analysis</u>

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

[a]Premix 5004, available from Dawes.

APPENDIX E

PHEASANT FLIGHT

Ingredient	Number of Pounds
Corn	1108
Soybean meal, 44%	282
Oats	200
Wheat middlings	200
Alfalfa, 17%	75
Meat and bone meal, 50%	60
Salt	5
Dicalcium phosphate	30
Limestone	30
Premix[a]	10
	2000

Calculated Analysis

Crude protein, %	16.00
Fat, %	3.51
Fiber, %	5.30
Calcium, %	1.30
Phosphorus, available %	.55
M.E., Cal/lb.	1259

[a]Premix 5004, available from Dawes.

APPENDIX F

TURKEY BREEDER

Ingredient	Number of Pounds
Corn	1269
Soybean meal, 49%	285
Wheat middlings	100
Alfalfa, 17%	60
Fish meal, 60%	60
Meat and bone meal, 50%	50
Whey, dried	50
Salt	7
Dicalcium phosphate	30
Limestone	77
Premix[a]	12
	2000

Calculated Analysis

Crude protein, %	17.00
Fat, %	3.10
Fiber, %	4.15
Calcium, %	2.35
Phosphorus, available %	.60
M.E., Cal/lb.	1280

[a]Premix 5004, available from Dawes.

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