



The effect of pre-adult and adult light on reproductive performance of white leghorn pullets
by Thomas W Wilcox

A THESIS Submitted to the Graduate Faculty In partial fulfillment of the requirements for the degree
of Master of Science in Animal Industry

Montana State University

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Abstract:

Egg production of White Leghorn pullets subjected to light-dark cycles of 20, 16, and 12 hours was investigated. Pullets were pre-conditioned on light-dark ratios of 12-12, 8-12, 12-8, 4-12, and 12-4 from 12 to 18 weeks of age. The birds were then re-randomized and given the same light-dark ratios to 54 weeks. Observations made during the experiment were age at first egg, rate of production to 54 weeks of age, number of eggs laid during the first 100 days of production, and egg weights.

Pullets exposed to 12 hours of pre-adult dark per cycle laid their first eggs at approximately the same average time. Those that received less than 12 hours of dark per cycle were retarded from 5 to 17 days.

Birds receiving 12 hours of adult light per cycle were nearly equal in response. Those that received less than 12 hours of light per cycle were retarded from 21 to 34 days.

In rate of production to weeks, 12 hours of adult light increased the rate of lay, shorter lengths reduced rates. Pre-adult light had no effect on rate.

In number of eggs to 100 days, 12 hour adult light increased numbers of eggs, shorter photoperiods reduce egg numbers. Pre-adult light had no effect on egg numbers.

Egg weight was not affected by the various lighting regimes.

No interactions were found between pre-adult and adult light in any of the observations.

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REPRODUCTIVE PERFORMANCE OF
WHITE LEGHORN PULLETS

by

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ABSTRACT

Egg production of White Leghorn pullets subjected to light-dark cycles of 24, 20, and 16 hours was investigated. Pullets were pre-conditioned on light-dark ratios of 12-12, 8-12, 12-8, 4-12, and 12-4 from 12 to 18 weeks of age. The birds were then re-randomized and given the same light-dark ratios to 54 weeks. Observations made during the experiment were age at first egg, rate of production to 54 weeks of age, number of eggs laid during the first 100 days of production, and egg weights.

Pullets exposed to 12 hours of pre-adult dark per cycle laid their first eggs at approximately the same average time. Those that received less than 12 hours of dark per cycle were retarded from 5 to 17 days. Birds receiving 12 hours of adult light per cycle were nearly equal in response. Those that received less than 12 hours of light per cycle were retarded from 21 to 34 days.

In rate of production to 54 weeks, 12 hours of adult light increased the rate of lay, shorter lengths reduced rates. Pre-adult light had no effect on rate.

In number of eggs to 100 days, 12 hour adult light increased numbers of eggs, shorter photoperiods reduce egg numbers. Pre-adult light had no effect on egg numbers.

Egg weight was not affected by the various lighting regimes.

No interactions were found between pre-adult and adult light in any of the observations.

INTRODUCTION

Numerous investigations concerning various lighting systems for chickens have been conducted since the early 1920's. Yet many questions concerning light-dark ratios are still unanswered. With the advent of the windowless house, it is now possible to study the effects of light-dark cycles that deviate from 24 hours. Many workers have studied the effects of varying amounts of light during the growing and reproductive periods of birds. Whether or not the effects of light given during the growing period are independent of the effects of light given during the adult period has not been established. With these points in mind, a study was conducted to determine the effects of pre-adult and adult light-dark cycles and ratios on performance of chickens.

REVIEW OF LITERATURE

The effects of the length of the photoperiod on the rate of egg production is well known. Under natural conditions, chickens attain maximum production during the spring months and continue in high production up to the longest day of the year or shortly thereafter. As the days become shorter, egg production begins to drop and the lowest levels are usually reached in late fall and early winter. Whetham (1933) has shown that egg production varies for flocks located at different latitudes, with maximum production occurring in the season with the longest days.

Response of Chickens to Adult Light-Dark Cycles

Early investigators simulated spring and summer day-lengths by using artificial morning or evening lights.

History on the use of artificial light to provide sexual stimulus for birds is not clearly defined, although Dougherty (1922) asserts, that the use of artificial light is of American origin. However, Baker et al (1932) apparently had information concerning the use of artificial light in Spain more than a century ago for the purpose of increasing egg production during the winter months.

Fairbanks (1924) demonstrated that proper illumination of both floor and roosts is important in obtaining a more uniform response from all birds. If illumination of roosts was poor, several birds failed to come down to feed even though the floor was properly illuminated. In order to avoid this, he recommends raising the light source high enough so that the perches will be properly illuminated, as well as the floor.

Exposing hens to ultra-violet light 10 minutes daily for a period of

10 weeks resulted in substantial increases in egg production during the winter months (Hughes et al, 1925).

Kable et al (1928) found that lengthening the day during the winter months does not cause a greater intake of feed unless the lengthened feeding time is accompanied by heavier egg production.

Rowan (1925) in experiments with juncos, and later with crows, showed that a relationship exists between the length of day and the development of the gonads and that this relationship is independent of available feed (cited by Dakin, 1934). Bissonnette (1933a) repeated Rowan's work and agreed with him but with one exception. Rowan believed that gonad development was the result of increased exercise provided by the increased length of light, whereas Bissonnette showed that the factor responsible for gonad development is light absorption rather than exercise.

In work with ferrets, Bissonnette (1932) found that by lengthening the day with artificial light he could induce oestrus in females during the winter. Ferrets normally come into oestrus in April. Controls failed to undergo any sexual change. Similar results with ferrets were again reported by Bissonnette (1933b). During this year he noticed that female ferrets restricted to about $7\frac{1}{2}$ hours of light per day went off heat. Females seemed to be affected more by light than males were, although light induced some increase in germ-cell activity and a great increase in interstitial cell mass in the males. Sexual activity was also increased in the males.

Cole (1933) subjected mourning doves to prolonged periods of light during the winter season and was able to induce mating resulting in fertile eggs and viable young.

Egg production in chickens can be increased by using morning lights during the winter months (Tomhave and Mumford, 1927; and Nicholas et al, 1944). Similar results with turkeys were reported by Albright and Thompson (1933); Scott and Payne (1937); and Wilcke (1939).

Morning light does not increase the annual egg production, but increases production during the winter months when it is normally low and decreases production during the spring months when it is normally high (Payne and Simmons, 1934; and Ogle and Lamoreux, 1942).

Nine hours of light retarded egg production in Bronze turkeys, according to Asmundson and Moses (1950). Light period of 11 and 12 hours resulted in a slower response than 15 hours, whereas hens on a 13 hour photoperiod started to lay slightly later than those receiving 14 or 15 hours. White Plymouth Rock pullets exposed to more than 12 hours of light per day attained sexual maturity earlier than those receiving less light per day (Muller et al, 1951).

The rate of egg production is proportional to daily light period. A maximum rate is reached when the daily light period is about 13 or 14 hours (Byerly, 1957). He reported that wide individual differences exist with respect to minimal daily periods of illumination required for egg production and response to increased daily light. This is in agreement with work done by Harper (1949) who concluded that turkey hens differ in their response to light stimulus. High producing females exhibited a faster response to artificial light stimulation than low producing hens.

Riley and Byerly (1943) compared Rhode Island Red Hens that received 14 hours of artificial light to a similar group receiving natural light from December 1 to March 1. The hens (97 in each group) started in a

similar molt condition and were practically out of egg production. The light-treated group was laying at a rate of about 46 per cent at 5 weeks and 68 per cent at 11 weeks, while the control group laid at a rate of 10 and 20 per cent respectively during the same weeks. Production in the control group was less than 15 per cent during the first 10 weeks and went up to 37.2 per cent during the last week. It was concluded that while increased light stimulates egg production in hens which have not finished molting, the progress of the molt is not affected. The foregoing reports were concerned with the use of supplemental light for part of the night. Investigations were also made with all-night lights.

Perhaps the first persons to note the response to all-night lights by fowl were early poultrymen who forgot to turn their lanterns off at night; or perhaps the early users of natural gas in this country. Kennard (1929) was one of the early investigators to study the stimulatory effects of all-night illumination. He demonstrated that the use of uninterrupted light was satisfactory for stimulating egg production.

Penquite and Thompson (1933, 1935, 1940) subjected Single Combed White Leghorn hens to 24 hours of daily lights. Studies over a 10-year period showed that the lighted birds reached a peak in production during November and December, whereas the controls reached their maximum rate of production in March, April and May. The use of continuous light did not increase or decrease the total egg production significantly. They also observed pullets to be less responsive to continuous light than yearling hens. Furthermore, they noted that constant light did not increase feed consumption. Milby and Thompson (1941) in their studies with turkey poults, also found that

all-night lights did not increase feed consumption when compared to normal daylight.

White and pearl guineas were caused to mature during the winter by exposing them to constant light (Davis, 1943). According to Baldini et al (1954) quail have been stimulated to egg production as early as 139 days of age when exposed to continuous light other than during the normal breeding season.

Turkey hens exposed to continuous light laid significantly more eggs than hens receiving natural light during the winter (Davis, 1948). Asmundson and Moses (1950) in their studies with turkeys, reported that hens receiving continuous light started laying significantly earlier than those exposed to 14 or 15 hours of light.

Exposing laying chickens in hot weather to all-night lights or artificial light from midnight to daylight, did not appreciably affect the egg production, feed consumption, or live weight when compared to birds receiving normal daylight, according to Heywang (1945).

Ryan et al (1959) using various breeds and strains of chickens, reported that hens exposed to all-night lights laid 5 per cent more eggs on a hen-day basis than a 14-hour light group at the end of 12 weeks, and 1.8 per cent more at the end of a 48-week period.

The converse of continuous light is continuous darkness. Although darkness allegedly inhibits egg production, Wilson and Woodard (1958) found that hens kept in complete darkness for five weeks continued to lay eggs. Some hens ceased production during this period, while others that previously had paused came into production.

In recent years workers have studied the influence of the dark period

on gonadal response. This was accomplished by interrupting the light period with dark periods. Weber (1951) has shown that various patterns of intermittent light give greater responses than the same amount of light in a single photoperiod. Kirkpatrick and Leopold (1952, 1953) observed similar results in their studies with quail. They concluded that the period of darkness is an inhibiting factor in this species, and suggest that the duration of the dark period is a major controlling factor in the photoperiodic responses. A similar conclusion was made by Jenner and Engles (1952) in their studies with juncos and white throated sparrows.

Photoperiodic responses of white crowned sparrows were studied by Farner et al (1953a). They obtained response by using various periods of interrupted light, the greatest coming from birds subjected to alternate periods of about one hour of light and one hour of dark throughout the experiment.

In different tests by Wilson and Abplanalp (1956), S. C. White Leghorn pullets were given artificial light during 6 intervals which were set to begin every 4 hours and to last 90, 60, 45, 15, 5 and 1 minute periods. In some of the experiments an equivalent amount of light was given daily in one continuous period and in others either 14 or 24 hours of continuous light was given. The results showed that intermittent light generally gave higher egg production than the same amount of continuous light.

The time of oviposition can be altered by using various lengths of intermittent light periods (Lanson and Sturkie, 1958).

A comparison of production of Leghorn hens receiving 4 light periods per day, 2 of one-hour duration during the daytime and 2 of 15-minutes duration at night, to the conventional 14-10 hour light-dark cycle were conducted by Wilcox et al (1960). Intermittent light delayed sexual maturity by an average of 5.2 days. Although the conventionally lighted birds came into production earlier, both groups laid at approximately the same rate once they were both in production. Approximately one-third of the eggs produced by the intermittent lighted birds were laid from 8 a.m. to 2 p.m. If the birds were laying randomly throughout the day, one-fourth of the eggs would be expected to have been laid during this time.

Studies have been conducted using diminishing periods of light. Baker et al (1932) reported that decreasing the daily light period from 15 hours to 9 hours almost prevents reproduction in the field mouse. They also observed that the female is chiefly affected by light changes. These results seem to agree with numerous reports of decreased or discontinued reproduction in various avian species when they are receiving decreasing periods of daily light.

Lengthening or decreasing the normal 24 hour day influences reproductive response. Byerly and Moore (1941) compared 26 hour days (14 light-12 dark) to natural daylight, continuous light and the conventional 14-10 hour cycle. They found that average clutch length and per cent production increased for the birds subjected to the 26-hour cycle.

Ostmann and Biellier (1958) subjected Leghorn pullets to various day-lengths ranging from 21 to 42 total hours of equal light and dark. They reported that days greater than 24 hours in length increased clutch length

and hen-day egg production, whereas days less than 24 hours decreased clutch length and hen-day egg production.

Response of Chickens to Adolescent Light-Dark Cycles

Several investigators have studied the effects of various amounts of light given during the growing period upon subsequent sexual maturity and egg production. Callenbach (1944) reported that continuous light during the growing and laying period appeared to inhibit the expression of sexual maturity of a considerable number of exposed pullets and prevented a higher ovulation intensity during the entire laying period. Similar results were reported by Wilson et al (1956), Shutze et al (1959), and Bowman and Archibald (1959). However, Carson et al (1958) reported that continuous light given from 15 weeks of age had no effect on sexual maturity of pullets.

Tomhave (1954) compared the performances of October hatched New Hampshire pullets exposed to normal daylight with those that were exposed to supplemental artificial light to simulate the length of day of pullets hatched in March. The length of artificial illumination varied from 1 hour in October to 5 hours in December. After 23 weeks of age all birds were exposed to 14 hours of light per day. Age at sexual maturity was retarded 7 to 14 days in the group receiving supplemental light. Similar results were reported with White Leghorn pullets under southwestern conditions by Lowe and Heywang (1961).

Lert et al (1960) restricted Leghorn pullets to 8 hours of light daily from 8 to 12 weeks of age, and 6 hours daily from 12 to 20 weeks. Controls received normal daylight. At 20 weeks both groups were exposed to a constant 14 hour day length throughout a 12-month trial. Results indicated that light restriction significantly increases total egg production. The

restricted group reached a higher maximum rate of production than did the controls. Similar results were obtained by Platt (1955), Marr et al (1957, 1960), Shutze et al (1960), and McCartney et al (1961).

Age at which pullets reach sexual maturity is increased as daily light increases, and decreases as daily light decreases, according to Morris et al (1958). They further state that the rate at which the length of day is changing is more important than the length of day.

A relatively new method of exposing chickens to artificial light is the so-called "stimulight", developed by King (1959). He subjected chicks during the first 5 months of age to 6 hours of light and 18 hours of darkness. Then from 5 months of age the pullets received a daily light increase of 18 minutes per week, until they reached 24 hours of continuous light daily. He compared this system with the conventional 14 hour lighting system, and found that "stimulight" increased egg production approximately 5 per cent. These results agree with those of Lawatsch et al (1960). However, McCartney et al (1960) and Miller and Sanford (1960) failed to increase production by the use of gradual increases in day length. Marr et al (1960) exposed 2 strains of chickens to gradually increasing day length. They obtained an increased egg production in the group of White Leghorns but not the group of White Rocks.

Light Effect Upon Egg Size

Early work indicates that egg size was not affected when chickens were exposed to various amounts of supplemental light in comparison to eggs laid by chickens receiving natural light (Parkhurst, 1933). These results agree with those of Wilcke (1939) in his studies of turkeys.

Results in the last few years of studies concerning egg size as affected

by lighting systems have been conflicting. Bowman and Archibald (1959) reported that pullets reared under decreasing day length laid heavier eggs and produced at a higher rate than those reared under natural daylight.

Lert et al (1960) restricted Leghorn pullets to 8 hours of light per day from 8 to 12 weeks of age, and 6 hours per day from 12 to 20 weeks of age. Controls received normal daylight. At 20 weeks both groups were subjected to a constant 14 hour day length throughout a 12-month trial. They found no significant difference in egg weight at 6½ months. However, Shutze et al (1960) found pullets reared under natural light and continuous light laid eggs significantly heavier than eggs from pullets reared under 8 hours of light per day.

Lowe and Heywang (1961) found little difference in the size of eggs from birds exposed to 16 hours of light during the growing period compared with egg size of controls receiving natural light (10 to 12 hours).

Stiles and Dawson (1961) reported that hens subjected to intermittent and continuous light laid eggs with a significantly greater average weight and albumen height than eggs from the control birds which received 14 hours of light.

Light Intensity

Nicholas et al (1944) concluded that low light intensity provides the necessary stimulation for egg formation and that there is no differential response to light intensity provided by artificial illumination within the limits of their study. They reported that light intensity, varying from 0.5 to 38.0 foot candles had no effect on the degree of reproductive response in S. C. White Leghorn and Barred Plymouth Rock pullets.

Asmundson et al (1946) reported that light intensity of about 2 foot

candles produced the maximum response in the turkey. Low intensity of 0.3 to 1.0 foot candles produced a slower response. A light intensity of less than 0.1 foot candle had no effect (compared to unhoused, unlighted birds) on egg production. Housing turkeys without artificial lights retarded egg production.

Transmission of Light Stimulus

Bissonnette (1933a, 1936) suggests the following mode of action of light: Light receptors of the eye are stimulated by the increase of daily exposure to long wave light. Short wave light is slightly inhibiting to sexual response. The stimulus is then conveyed to the anterior lobe of the pituitary which releases a gonad-stimulating hormone. This hormone stimulates the ovary or testis to activity. Increased sex stimulation leads to increased yolk production which in turn leads to increased feed consumption.

Carry-over Period

Hammond (1952) in studies with mink suggest that the stimulatory effects of light can be stored for long periods. Similar conclusions were made by Farner et al (1953b) and Wilson et al (1956). These researchers seem to agree on the theory that the light sensitive gonadotropic mechanism, which probably involves both the anterior pituitary and the hypothalamus, becomes active almost immediately after commencement of the photoperiod and has a persistent carry-over period of activity after the cessation of light.

Farner et al (1953b) mentions the possibility that the synthesis of gonadotropins may involve a light-dependent reaction. If so, perhaps the carry-over period is a period of dissipation of the gonadotropins down to an ineffective level. They also suggest the possibility that the transfer of gonadotropins into the blood stream involves a light-dependent reaction.

Should this be the case, perhaps the "carry-over" period is the time required for gonadotropins in the circulatory system to fall below the threshold concentration. Another possibility is that the light-dependent reaction may be in the hypothalamus where it produces a substance which puts forth a humoral control over the anterior pituitary.

MATERIALS AND METHODS

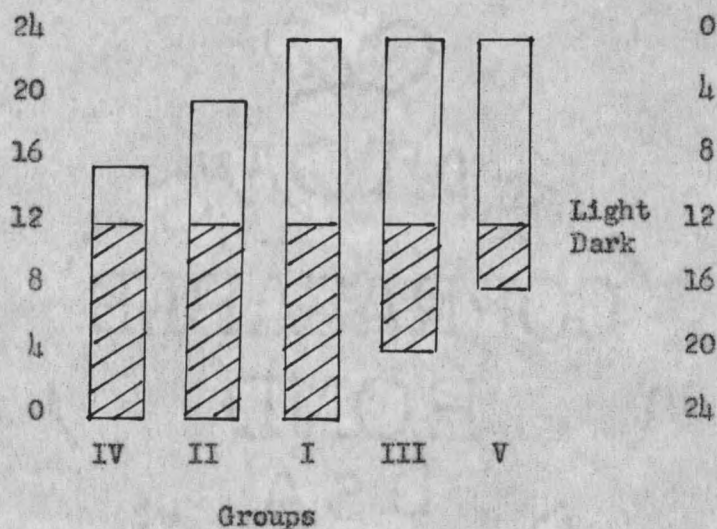
Two experiments were conducted at the Montana State College Experiment Station Poultry Farm. Chicks were brooded in two 12' x 17' pens. The windowless laying house contained ventilating fans which were covered with black louvers to assist in sealing out daylight. Thermostatically controlled ventilator fans helped maintain more uniform room temperatures. Heat for the house was supplied by body heat radiated by the birds. The laying house was 87' x 25' in size, consisting of a feed room, five 15' x 20' pens, and a hallway from which the five pens were serviced. Each pen was equipped with two double rows of individual cages. The size of each individual cage was 8" x 16". There were 30 individual cages on each side, making 60 cages per double row or a total of 120 cages for an entire pen. An automatic water trough was located between each double row of cages. Feed troughs were located at opposite sides of the cages from the waterers. Artificial light was obtained from four evenly-spaced, 40-watt incandescent light bulbs, located directly over the cages.

Time-clocks, regulated to operate at 16, 20, and 24 hour cycles, were located in the hallway. Each time-clock was equipped with a red 7-watt bulb which came on with the pen light, and turned off with the pen light. This enabled the attendant to know whether the pen light was on or off and thus he could avoid entering the unlighted pen accidentally. When it was necessary to enter an unlighted pen, a flashlight was used by the attendant to enable him to record the individual records and gather eggs. The flashlight was covered in such a way as to cause the light rays to converge in a small area.

Identical procedures were used in both experiments, with two exceptions, viz., chicks were hatched in different seasons and a greater number (365) were employed in the second experiment. The chicks in the first experiment were hatched August 15, 1959, whereas those in the second experiment were hatched March 23, 1960. The chicks used in both experiments were hatched from eggs of the Cornell Random-bred flock obtained from Purdue University. The day after the chicks were hatched they were moved to the brooder house, where they received natural light (approximately 14 hours, decreasing to approximately 9 hours per day in the first experiment; approximately 12 hours increasing to approximately 15 hours in the second experiment) to 12 weeks of age. At this age 268 pullets were moved to the laying house where they were distributed at random among 5 different groups, each composed of from 51 to 55 birds. The pullets were subjected to the following light-dark treatments:

<u>Pen or Group Number</u>	<u>Hours-light</u>	<u>Hours-dark</u>	<u>Total cycle</u>
I	12	12	24
II	8	12	20
III	12	8	20
IV	4	12	16
V	12	4	16

Graphically the treatments were as follows:



Pullets were exposed to adolescent or pre-adult light for a period of 6 weeks. At 18 weeks of age, one-fifth of each group was left in the same pen and the remaining four-fifths were distributed equally among the other 4 pens. The pens continued to receive the same light treatments as described earlier. The light treatments from 18 to 54 weeks of age is referred to as adult light. Table I shows the resulting pre-adult and adult light-dark treatment combinations.

All birds were fed the standard Montana State College laying ration composed of the following formula:

74 per cent ground barley
20 per cent 32% poultry concentrate*
6 per cent granulated limestone

*The concentrate provided for a balance of protein, vitamins, and minerals required in a laying ration.

Data concerning feed consumption were not recorded because the literature indicates that feed consumption is not increased by the use of light.

Monthly egg records consisted of 28 day periods. Eggs were collected once a day during the light period. Occasionally it became necessary to gather them in the dark as was explained previously. Observations were made on age at first egg (sexual maturity), number of eggs laid during the first 100 days of production, rate of production to 54 weeks of age, and egg weights. Analysis of variance was employed to analyze these observations. Data from 8 birds in each light-dark combination treatment were used in the analyses. Since there were 25 light-dark treatment combinations in both experiments the data of 400 birds were analyzed. One light-dark treatment combination (12-4, 12-4) in the first experiment had complete data for only 7 birds. The average data of these 7 birds were used as data for the missing entry.

Pre-adult and adult light treatments were subdivided into individual degrees of freedom which permitted subdivision of the treatment sums of squares. The mean squares of each degree of freedom was then compared to the appropriate experimental error mean square to give the selected treatment comparisons (Ostle, 1960). The following is a code used in the treatments that were subdivided:

A₁ = 12-12 pre-adult light

A₂ = 8-12 " " "

A₃ = 12-8 " " "

A₄ = 4-12 " " "

A₅ = 12-4 " " "

B₁ = 12-12 adult light

B₂ = 8-12 " "

B₃ = 12-8 " "

B₄ = 4-12 " "

B₅ = 12-4 " "

Egg weight data were collected only in the second experiment. Two egg samples were randomly selected from each light-dark treatment combination, making a total of ten eggs from each pen, or 50 eggs from all 5 pens. Eggs were collected for weighing once each month for 6 months.

RESULTS AND DISCUSSION

Effect of Light on Age at Sexual Maturity

A review of the literature indicates that light has a definite effect on sexual maturity of birds. The data from two replicates were analyzed to get an indication of the effects of both pre-adult and adult lights on sexual maturity. Sexual maturity was indicated by age at which the first egg was laid.

The analysis of variance presented in Table II showed that the effect of pre-adult light on sexual maturity was highly significant in these data, as were adult light effects. The subdivisions of both the pre-adult and adult light treatments show that both light-dark cycles (A_2A_3 vs A_4A_5 and B_2B_3 vs B_4B_5) and ratios (A_2A_4 vs A_3A_5 and B_2B_4 vs B_3B_5) have significant or highly significant effect on age at sexual maturity. Birds exposed to 20 hour pre-adult cycles matured approximately 5 days earlier than those exposed to 16 hour pre-adult cycles. Pre-adult short-light ratios caused the birds to mature an average of 11 days earlier than those subjected to pre-adult long-light ratios. When comparing the normal 24-hour cycle (A_1) to cycles less than 24 hour (rest) the difference was non-significant.

Hens exposed to 16-hour adult cycles matured approximately 8 days earlier than those exposed to 20-hour adult cycles. Adult long-light ratios caused the birds to mature an average of 27 days earlier than those subjected to adult short-light ratios. These results were the reverse of those obtained from the pre-adult light. Sexual maturity was significantly ($P < 0.01$) advanced in birds receiving the 12-12 adult cycle compared to the average maturity of birds receiving the other 4 cycles. This does not mean

that this cycle is superior to each individual cycle. Table III shows that the 12-4 adult cycle matured slightly earlier than the 12-12 adult cycle. The interaction between adolescent and adult light was non-significant, indicating that the effect of these two treatments are independent of each other. The difference between replicates was highly significant ($P < 0.01$). Perhaps this was partially caused by seasonal effect. Pullets in the first experiment were first exposed to adult light in early December, whereas those in the second experiment were first exposed in late July. There was also a highly significant ($P < 0.01$) interaction between both pre-adult light and replication, and adult light and replication.

The mean age at which the first egg was laid is shown in Table III. Pullets exposed to pre-conditioning light-dark cycles of 12-12, 8-12, and 4-12 matured at approximately the same age. In the 12-8 and 12-4 light-dark cycles, sexual maturity was retarded approximately 5 to 17 days respectively. Therefore, birds receiving long dark periods during the growing period matured earlier sexually than birds receiving long light periods. These results agree with work done by Callenbach (1944), Tomhave (1954), Wilson et al (1956), Shutze et al (1959), and Bowman and Archibald (1959), who found that light given in excess of 12 hours retarded sexual maturity. These results, however, disagree with work done by Carson et al (1958) who reported that sexual maturity of pullets was unaffected by exposing them to continuous light from 15 weeks of age.

Pullets exposed to adult light-dark cycles of 12-12, 12-8, and 12-4 laid their first egg at approximately the same average time, (Table III), thus no significant differences existed (Table IV). Pullets exposed to the 8-12 and 4-12 light-dark cycles were retarded 34 and 21 days respec-

tively. These results indicate that birds exposed to long adult light periods reached sexual maturity earlier than those subjected to long dark periods. Pullets on 4-12 adult light cycles matured earlier than those on 8-12 cycles, which is contrary to expectation. The difference might be the result of two factors which possibly affect sexual response, viz., length of light and frequency of light periods. Birds receiving the 4-12 light-dark cycle received light periods more frequently than did those exposed to the 8-12 light-dark cycle. Perhaps the "carry-over" period of activity suggested by Farner et al (1953b) has a slightly greater effect on sexual maturity than the longer light period. If this is so, then it would be expected that the 4-12 group would mature earlier than the 8-12 group.

Effect of Pre-Adult and Adult Light on Per Cent
Production to 54 Weeks of Age

The method used to compute the rate of lay was the number of eggs laid divided by the number of days after the hen commenced to lay to 54 weeks of age. The analysis of variance shown in Table V, indicated that the various pre-adult light periods resulted in no significant differences in the subsequent rate of lay. This is further illustrated by Table VI, which shows the average rate of production. However, we find in Figure 1, which shows the effect of pre-adult light on the number of eggs (per 80 hens) through 9 months, that the number of eggs is somewhat reduced in the 12-4 group during the first 8 months. This result seems to agree in part with work done by Callenbach et al (1944), who found that constant 24 hour light during the growing period reduced the intensity of lay during the entire laying period.

The effect on the rate of production due to adult light was highly significant, (Table V). Table VI shows that the control group laid at the highest average rate (73.2 per cent), followed in order by groups 3 (12-8), 5 (12-4), 2 (8-12), and 4 (4-12), which laid at an average rate of 69.0, 67.3, 65.5, and 62.8 per cent respectively. This difference was highly significant (B_1 vs rest).

Birds exposed to 20 hour light-dark cycles laid at an average rate of 67.2 per cent compared to 65.1 per cent for those exposed to the shorter 16 hour light-dark cycles. The difference between these cycles was non-significant (Table V).

The difference in the rate of production of long adult light-dark ratios (B_3 , B_5) and short adult light-dark ratios (B_2 , B_4) was highly significant (Table V). The average rate of production was 68.2 per cent for the long-light ratios compared to 64.1 per cent for the short-light ratios. It may be concluded then that the length of the light during the laying period is more important in obtaining maximum rate of lay to 54 weeks than the length of the cycle.

Birds exposed to 12 hours of adult light laid at the greatest average rate (Table VI). Differences in the rate of production between the 12 hour adult light groups were also highly significant (Table VII), with the control group superior to the other two groups.

Figure 2, clearly shows that the number of eggs laid is substantially increased by exposing chickens to 12 hours of adult light and reduced by exposing them to less than 12 hours of light. These results agree with those of numerous investigators.

One theory advanced to explain the adverse effect of lighting pullets during the growing period is that the pituitary becomes refractory to light before production commences (Carson et al 1958). The number of eggs (per 80 hens) in Figure 2 shows a sharp decline during the last laying period. It might be possible that the pituitary eventually becomes refractory to excess light during the laying period as it does during the growing period. All interactions concerning the effect of light on rate of lay to 54 weeks were non-significant.

Effect of Light on Number of Eggs to 100 Days

Intensity of lay, for the individual bird, decreases from the time of the first egg. Therefore, hens that have been in production for long periods are usually producing at lower rates than those that have been in production for short periods. An analysis of variance was performed to test differences in the number of eggs laid during the first 100 days of production as affected by the light treatments (Table VIII). The analysis of variance showed that pre-adult light had no significant effect to 100 days of production. This becomes evident by observing the average number of eggs laid to 100 days from time of the first egg (Table IX).

Table VIII shows that the differences in the adult light were significant ($P < 0.01$). The adult light treatment was subdivided to provide tests for selected treatment comparisons. The test comparing light ratios showed highly significant differences, with long light periods superior to short light periods. Birds exposed to long light periods laid an average of 73.2 eggs compared to an average of 64.8 eggs for those receiving short light periods. It is concluded that long adult light periods (12 hours) are more

conducive to reproductive response of chickens than short adult light periods (4-8 hours). These results agree with those of numerous investigators.

A comparison between adult light-dark cycles (Table VIII) shows that the different light cycles resulted in no difference in the number of eggs produced to 100 days. Birds exposed to 20-hour cycles averaged slightly more eggs (69.9) than those exposed to 16-hour cycles (68.1). A third comparison in Table VIII shows adult day-lengths shorter than 24 hours resulted in fewer eggs during the first 100 days. These results are similar to those reported by Biellier and Ostmann (1960) who found that days of less than 24 hours decreased clutch length and egg production.

Table X shows the effect of 12-hour adult light on the number of eggs laid to 100 days. The analysis of variance showed differences among the 12-hour adult light groups were significant ($P < 0.05$). Table IX shows that the control group laid a greater average number of eggs than did the 12-8 and 12-4 light groups. Hence, increasing the amount of light per 24 hours above a 1:1 ratio reduced the average number of eggs laid. All 2- and 3- way interactions were non-significant.

Comparing the rate of lay by analyzing the per cent production to 54 weeks and the number of eggs for the first 100 days of production resulted in similar findings. The main difference being that the effect due to replication was significant in the rate of lay to 54 weeks, whereas it was non-significant in the number of eggs for the first 100 days of production.

Effect of Pre-Adult and Adult Light on Egg Weight

The effects of the two lighting systems on egg weight were analyzed from data of the second experiment only. Collection of egg weight data

commenced at 34 weeks of age, which was after all birds came into production. The effects of both pre-adult and adult light on the variance of egg weight are shown in Table XI. The average weights of eggs in grams are shown in Table XII.

Neither pre-adult nor adult light systems had any significant effect upon egg weight. This result agrees with work done by Parkhurst (1933), Lert et al (1960), and Lowe and Heywang (1961), who found that various amounts of light during the growing and adult periods did not significantly affect egg weight.

The effect of age of the bird was statistically significant ($P < 0.01$) on egg weight. This is expected, however, because egg size increases with age of bird.

In future studies, it would be interesting to investigate the effects of various lighting systems on egg production longer than 54 weeks. Another interesting aspect would be to find out if the laying year is decreased by exposing hens to short light-dark cycles.

SUMMARY

Two experiments were conducted using S. C. White Leghorn chickens. The experimental birds receiving natural light from date of hatch to 12 weeks of age. The birds were then moved to the laying house, where they were randomly distributed among five different groups. The birds were housed in individual cages in pens receiving light-dark treatments of 12-12, 8-12, 12-8, 4-12, and 12-4 from 12 to 18 weeks of age. This was the pre-adult light period. When the birds were 18 weeks of age, one-fifth of each group was left in the same pen and the other four-fifths were moved and divided among each of the other pens. This was the adult light period.

Measured were age at first egg, rate of production to 54 weeks of age, number of eggs laid during the first 100 days of production, and egg weights. The data of 200 chickens in each experiment were analyzed.

An analysis of the effect of light on age at maturity indicated that 12-hour dark periods during the growing period resulted in early sexual maturity regardless of the length of the light periods. Adult light had the opposite effect on sexual maturity, i.e., 12-hour light periods advanced sexual maturity regardless of the length of the dark periods.

Birds exposed to 20-hour pre-adult cycles matured about 5 days earlier than those on 16-hour pre-adult cycles. Pullets receiving pre-adult long-light ratios were retarded on an average of 11 days.

Hens exposed to 16 hour adult cycles matured approximately 8 days earlier than those exposed to 20 hour adult cycles. Adult short light ratios were retarded an average of 27 days.

The various pre-adult light-dark cycles had no effect on subsequent rate of production to 54 weeks. On the other hand, adult light had a highly significant effect on the rate of lay to 54 weeks. Differences in the rate of lay between 20-hour and 16-hour cycles were non-significant. Birds exposed to long light ratios averaged 68.2 per cent production compared to 64.1 per cent for those exposed to short light ratios, the difference was highly significant ($P < 0.01$). Twelve hours of adult light resulted in a higher rate of lay than lesser amounts of light. The control group was superior in the 12 hour light groups.

Pre-adult light had no significant effect on the number of eggs laid to 100 days from time of the first egg. The effect of adult light was highly significant ($P < 0.01$). Light-dark cycles made no difference in the number of eggs produced to 100 days of production. Birds exposed to long light periods laid an average of 73.2 eggs compared to an average of 64.8 eggs for those receiving short light periods. Significant differences occurred between the groups receiving 12 hours of adult light, with the control groups superior to the other two 12-hour adult light groups. These results were similar to those obtained from the analysis of rate of lay to 54 weeks, except that when eggs laid to 100 days of production were used as the measurement of rate, the difference between replications was non-significant.

Six months egg weight data were analyzed from the second experiment. Both adolescent and adult lights did not significantly affect the size of eggs.

The analysis of variance for all observations showed that the interactions between pre-adult and adult light were non-significant.

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TABLE I

LIGHT-DARK TREATMENT COMBINATIONS

Pre-adult	12-12	8-12	12-8	4-12	12-4
Adult	12-12	12-12	12-12	12-12	12-12
Pre-adult	12-12	8-12	12-8	4-12	12-4
Adult	8-12	8-12	8-12	8-12	8-12
Pre-adult	12-12	8-12	12-8	4-12	12-4
Adult	12-8	12-8	12-8	12-8	12-8
Pre-adult	12-12	8-12	12-8	4-12	12-4
Adult	4-12	4-12	4-12	4-12	4-12
Pre-adult	12-12	8-12	12-8	4-12	12-4
Adult	12-4	12-4	12-4	12-4	12-4

TABLE II

ANALYSIS OF VARIANCE OF LIGHT EFFECT ON SEXUAL MATURITY

Source of Variation	Degree of Freedom	Sums of Squares	Mean Square	Calculated F-ratio
R Replication	1	6108	6108	12.70**
A Pre-adult light	4	17526	4381	9.11**
A ₂ A ₄ vs A ₃ A ₅	1	9647	9647	20.06**
A ₂ A ₃ vs A ₄ A ₅	1	2066	2066	4.30*
A ₁ vs rest	1	1716	1716	3.57
A ₂ A ₅ vs A ₃ A ₄	1	4097	4097	8.52**
B Adult light	4	78486	19621	40.79**
B ₂ B ₄ vs B ₃ B ₅	1	58861	58861	122.37**
B ₂ B ₃ vs B ₄ B ₅	1	5628	5628	11.70**
B ₁ vs rest	1	11947	11947	24.84**
B ₂ B ₅ vs B ₃ B ₄	1	2050	2050	4.26*
AB	16	8613	538	1.12
AR	4	7369	1842	3.83**
BR	4	6761	1690	3.51**
ABR	16	10612	663	1.38
Error	349	167723	481	-
Total	398	303198	---	-

* Significant at the 5 per cent level

** Significant at the 1 per cent level

TABLE III

MEAN AGE AT WHICH FIRST EGG WAS LAID

Adult light-dark cycle	Pre-adult light-dark cycle					Mean
	12-12	8-12	12-8	4-12	12-4	
12-12	176.3	164.1	174.8	166.9	184.0	173.2
8-12	206.7	203.2	199.3	198.8	227.8	207.2
12-8	164.8	170.2	185.8	170.9	183.2	175.0
4-12	186.2	197.2	194.6	184.6	206.0	193.7
12-4	166.0	168.9	168.4	172.1	183.0	171.7
Mean	180.0	180.7	184.6	178.7	196.8	184.2

TABLE IV

ANALYSIS OF VARIANCE OF 12 HOUR ADULT
LIGHT EFFECT ON AGE AT FIRST EGG

Source of Variation	Degree of Freedom	Sums of Squares	Mean Square	Calculated F-ratio
R Replication	1	893	893	2.19
A Pre-adult light	4	8233	2058	5.06**
B Adult light	2	433	221	.54
AB	8	3894	487	1.20
AR	4	4721	1180	2.90*
BR	2	591	295	.72
ABR	8	2211	276	.68
Error	209	85091	407	
Total	238	106077		

* Significant at the 5 per cent level

** Significant at the 1 per cent level

TABLE V

ANALYSIS OF VARIANCE OF LIGHT EFFECT
ON PER CENT PRODUCTION TO 54 WEEKS

Source of Variation	Degree of Freedom	Sums of Squares	Mean Square	Calculated F-ratio
R Replication	1	2560	2560	23.49**
A Pre-adult light	4	127	32	.29
B Adult light	4	4908	1227	11.26**
B ₂ B ₄ vs B ₃ B ₅	1	1304	1304	11.96**
B ₂ B ₃ vs B ₄ B ₅	1	383	383	3.51
B ₁ vs rest	1	3203	3203	29.39**
B ₂ B ₅ vs B ₃ B ₄	1	18	18	.17
AB	16	1324	83	.76
AR	4	271	68	.62
BR	4	561	140	1.28
ABR	16	1191	75	.70
Error	349	37932	109	
Total	398	48880		

** Significant at the 1 per cent level

TABLE VI

MEAN RATE OF PRODUCTION FROM TIME

FIRST EGG TO 54 WEEKS OF AGE

Adult light-dark cycle	Pre-adult light-dark cycle					Mean
	12-12	8-12	12-8	4-12	12-4	
12-12	74.1	74.6	72.6	74.5	70.4	73.2
8-12	68.4	65.3	66.4	64.1	63.1	65.5
12-8	69.9	68.0	67.1	67.7	72.4	69.0
4-12	62.8	61.9	61.4	63.6	64.2	62.8
12-4	65.9	71.2	69.9	65.3	64.2	67.3
Mean	68.2	68.2	67.5	67.0	66.9	67.6

TABLE VII
ANALYSIS OF VARIANCE OF 12 HOUR ADULT LIGHT EFFECT
ON PER CENT PRODUCTION TO 54 WEEKS

Source of Variation	Degree of Freedom	Sums of Squares	Mean Squares	Calculated F-ratio
R Replication	1	781	781	7.30**
A Pre-adult light	4	150	37	.35
B Adult light	2	1481	740	6.92**
AB	8	942	118	1.10
AR	4	104	26	.24
BR	2	144	72	.67
ABR	8	773	97	.91
Error	209	22337	107	-
Total	238	26712	-	-

** Significant at the 1 per cent level

TABLE VIII

ANALYSIS OF VARIANCE OF LIGHT EFFECT

ON NUMBER OF EGGS TO 100 DAYS

Source of Variation	Degree of Freedom	Sums of Squares	Mean Square	Calculated F-ratio
A Replication	1	480	480	3.48
A Pre-adult light	4	248	62	.45
B Adult light	4	11160	2790	20.22**
B ₂ B ₄ vs B ₃ B ₅	1	5645	5645	40.91**
B ₂ B ₃ vs B ₄ B ₅	1	263	263	1.91
B ₁ vs rest	1	4865	4865	35.25**
B ₂ B ₅ vs B ₃ B ₄	1	11160	11160	80.87**
AB	16	1937	121	.88
AR	4	486	121	.88
BR	4	945	236	1.71
ABR	16	1255	78	.57
Error	349	48031	138	-
Total	398	64579	-	-

** Significant at the 1 per cent level

TABLE IX

MEAN EGGS TO 100 DAYS OF PRODUCTION
FROM TIME OF FIRST EGG

Adult light-dark cycle	Pre-adult light-dark cycle					Mean
	12-12	8-12	12-8	4-12	12-4	
12-12	77.9	76.9	76.3	80.9	76.6	77.7
8-12	69.0	66.9	68.0	66.4	63.7	66.8
12-8	71.7	73.2	72.1	72.7	75.3	73.0
4-12	62.7	59.5	64.5	66.2	61.1	62.8
12-4	73.1	80.2	73.5	70.6	69.5	73.4
Mean	70.9	71.4	70.9	71.4	69.2	70.7

TABLE X

ANALYSIS OF VARIANCE OF 12 HOUR ADULT LIGHT
EFFECT ON NUMBER OF EGGS TO 100 DAYS

Source of Variation	Degree of Freedom	Sums of Squares	Mean Squares	Calculated F-ratio
R Replication	1	0	0	0
A Pre-adult light	4	290	73	.50
B Adult light	2	1095	547	3.77*
AB	8	1185	148	1.02
AR	4	409	102	.70
BR	2	263	131	.90
ABR	8	853	107	.74
Error	209	30260	145	-
Total	238	34355	-	-

* Significant at the 5 per cent level

149528

TABLE XI

ANALYSIS OF VARIANCE OF LIGHT EFFECT ON EGG WEIGHT

Source of Variation	Degree of Freedom	Sums of Squares	Mean Squares	Calculated F-ratio
A Pre-adult light	4	93	23	1.21
B Adult light	4	154	38	2.00
C Time	5	1390	278	14.63**
AB	16	272	17	.89
AC	20	280	14	.74
BC	20	359	18	.95
ABC	80	1153	14	.74
Error	150	2892	19	-
Total	299	6593	-	-

** Significant at the 1 per cent level

TABLE XII

MEAN WEIGHT OF EGGS IN GRAMS (6 MONTHS)

Adult light-dark cycle	Pre-adult light-dark cycle					Mean
	12-12	8-12	12-8	4-12	12-4	
12-12	58.1	55.7	58.4	57.5	57.0	57.3
8-12	59.7	59.7	55.3	58.0	59.7	58.5
12-8	59.8	58.1	57.6	58.2	58.6	58.5
4-12	60.7	59.3	59.6	59.2	57.2	59.2
12-4	58.0	57.4	58.0	57.2	56.5	57.4
Mean	59.1	58.0	57.8	58.0	57.8	58.2

Number of Eggs (Per 80 hens)

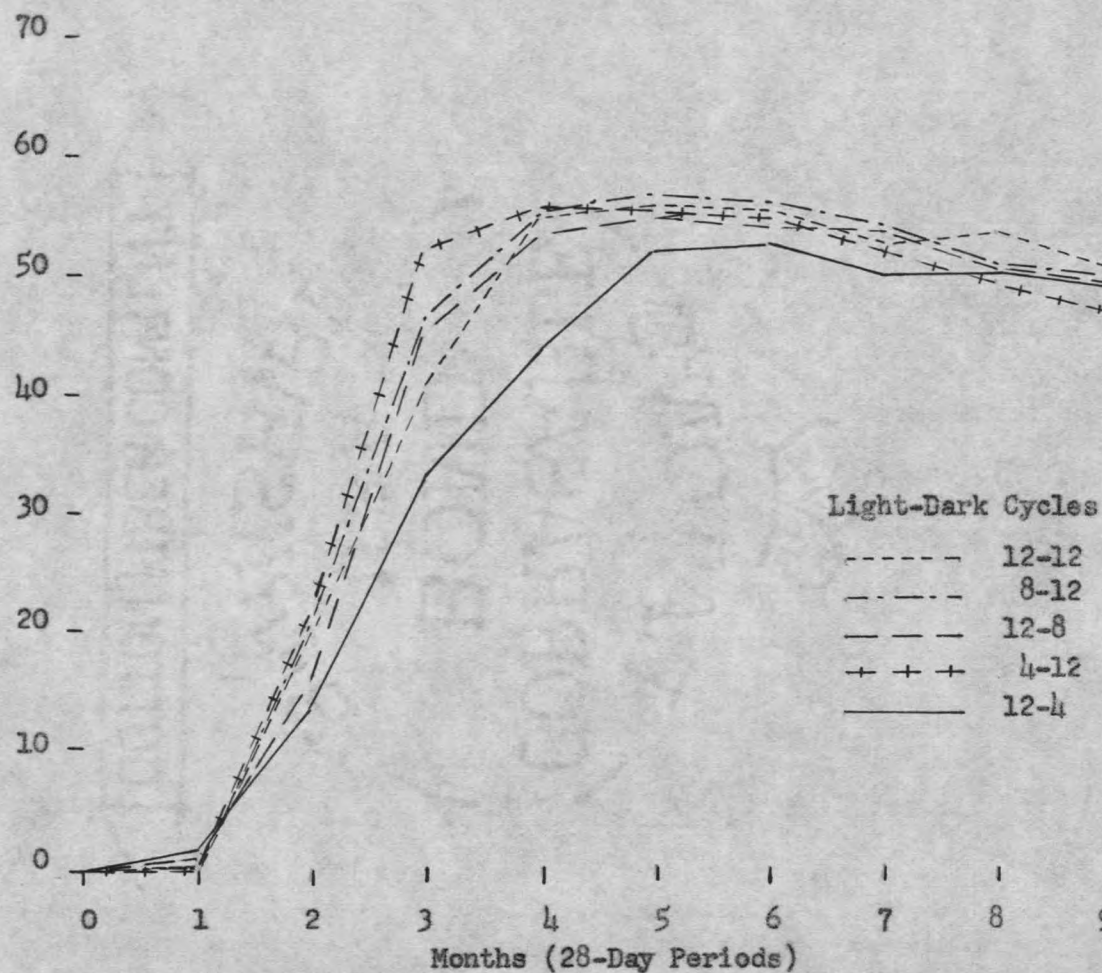


Figure 1. Effect of Pre-Adult Light on Average Daily Egg Production

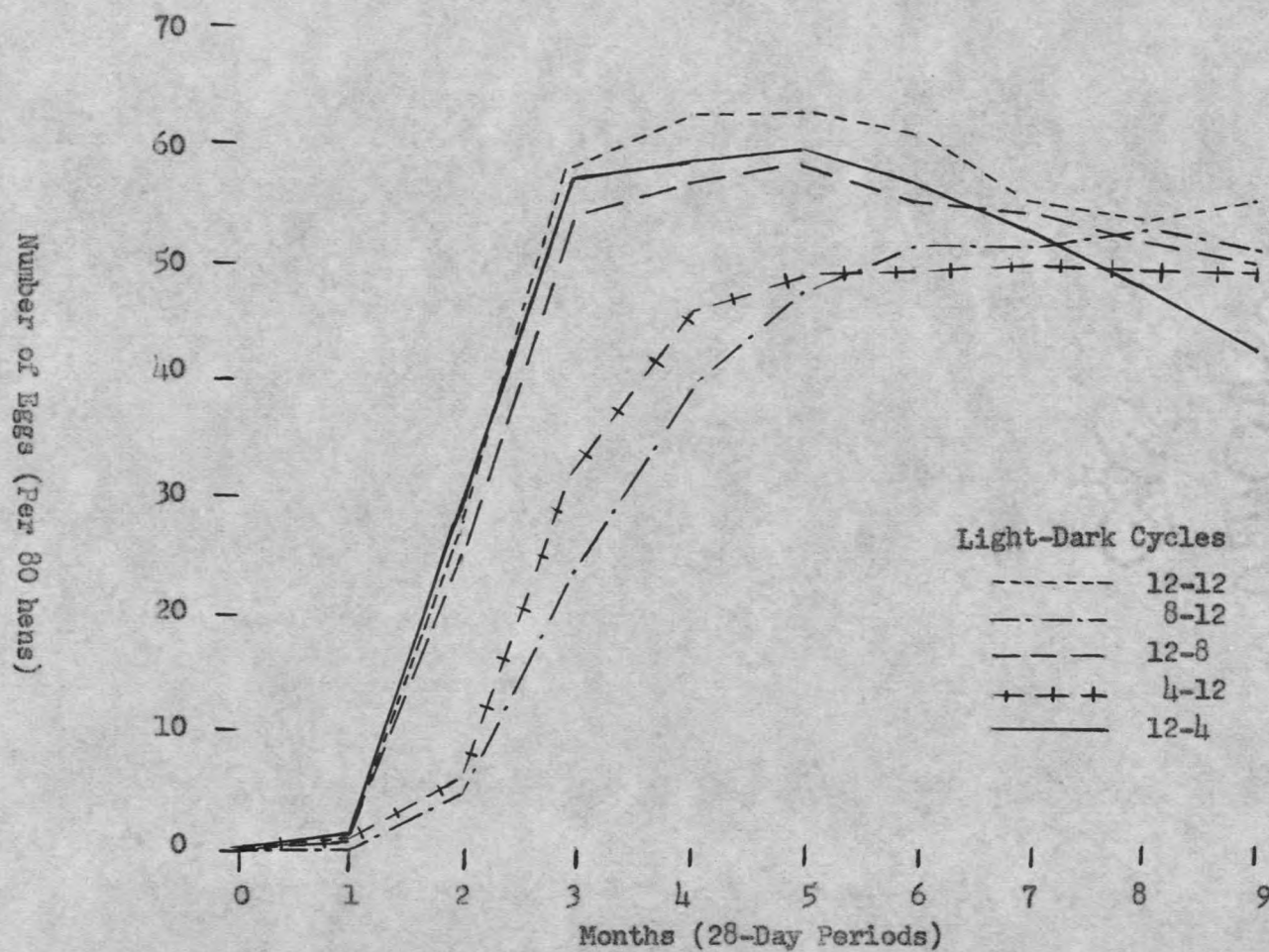


Figure 2. Effect of Adult Light on Number of Eggs

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performance of white leghorn
pullets

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