# LIGHT SOURCE AS A FACTOR IN GROWTH AND REPRODUCTION AND THE INFLUENCE OF THE OPPOSITE SEX ON REPRODUCTION IN TURKEYS

by

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(ABSTRACT)

This study evaluated the effects of three light sources (sodium vapor, daylight fluorescent, and incandescent) on growth and reproduction in turkeys, and the influence of the opposite sex on reproduction when using these three light sources. The influence of the various treatments as potential stressors was also evaluated. Ninety male and 324 female Large White turkeys were reared in single-sex pens under one of the three previously mentioned light sources from 8 to 22 weeks of age. All males and females were placed under lights restricted to 6 hours (h) of light per day at an intensity of 21.6 lux when they were 22 weeks of age. At 33 weeks of age, males were exposed to 16 h of light per day under the same light sources under which they were reared at intensities of either 21.6 or 86.1 lux. At 35 weeks of age, females were reassigned to the various light sources to achieve all possible combinations of adolescent and breeder light source. Light was provided 16 hours per day at an intensity of 53.8 lux during a 20 week egg production cycle. Within this design, females were housed in either (a) pens with a male physically present, (b) pens with a male visually and vocally present, or (c) pens completely isolated from males.

Feed efficiency of males and females was unaffected by adolescent light source treatment. Body weight of males and females was also unaffected through 22 and 14 weeks, respectively.

In the breeder phase of the experiment, body weight, hen-housed and hen-day egg production, fertility, hatchability, days to first egg, egg weight, egg specific gravity, and immune response of females were unaffected by either adolescent or breeder light source. For males, semen volume, semen concentration, semen quality and immune response were unaffected by breeder light source.

The presence or absence of males had no effect on body weight, fertility, hatchability, days to first egg, egg weight, egg specific gravity, or immune response. Hen-day egg production was significantly higher for females with a male in the pen, followed by females having males visually and vocally present in an adjacent pen, and hens isolated from males. The presence or absence of males had no effect on hen-housed egg production. In males, the presence or absence of females had no significant effect on either immune response or semen volume, concentration, or quality.

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# INTRODUCTION

Agricultural enterprises have been placed at an economic disadvantage in recent years because of increases in the cost of energy. Highly mechanized farm operations have been most severely affected because of their extensive use of energy sources. Because of high energy costs, it has been mandatory to reduce energy usage.

The turkey industry extensively uses oil, gas, and electricity, and is constantly looking for ways to become more energy efficient. One approach is to use light sources that will provide maximum illumination per unit of energy. Growth, agonistic behavior, and reproduction of the turkey are influenced by a combination of daylength, light intensity, and wavelength of the light. The most economical light source obviously is natural daylight, but daylength varies depending on the season of the year. It is therefore necessary to provide supplemental light during the late Fall and Winter months in order to maximize reproductive performance. Under these circumstances, energy consumption is relatively high. Within the past few years, more economical light sources have been developed, thus it is of interest to elucidate further their effects on reproductive efficiency, stress, and agonistic (aggressive) behavior.

Comparative lamp characteristics and relative efficiencies of various light sources for possible use by turkey breeder flock managers are

| Light Source | Average Lumens Per Watt ** | Average Lamp Life (hours) |
|---|---|---|
| Incandescent | 15 | 1,100 |
| Metal Halide | 64 | 6,000 |
| Fluorescent | 68 | 20,000 |
| Mercury Vapor | 37 | 24,000 |
| High Pressure Sodium Vapor | 72 | 24,000 |

Source: Hubbell Lighting Buyer's Guide (1987), Hubbell Lighting Division, Christiansburg, Virginia.

** Actual lumens/watt varies somewhat depending on the bulb wattage.

From the above information, it is obvious that the incandescent lamp is inferior to the other light sources in terms of lamp life and energy efficiency. Lumens per watt for fluorescent and sodium vapor lamps are four and five times that of incandescent lamps, respectively, and lamp life of fluorescent and sodium vapor lamps is 20 and 22 times that of incandescent lamps, respectively.

Given this information, a typical turkey breeder house 18 meters wide and 110 meters long would require 4 rows of 28 incandescent lamps (100 watts each) or 112 bulbs total to provide adequate illumination. This would require 168 kilowatts of electricity per day. Assuming a cost of 4.07 cents per kilowatt-hour of electricity (Source: Appalachian Power Company, Christiansburg, Virginia), it would cost $6.83 per day to operate the bulbs for 15 hours per day, or $2295 per year assuming the house is in use 48 weeks per year. Fluorescent lamps could provide the same number

of lumens for $1.51 per day, or $507 per year while sodium vapor lamps would cost only $1.42 per day, or $478 per year to operate. These values represent annual savings due to utilization of fluorescent and sodium vapor light sources of $1788 and $1817 per year, respectively, in operating only one turkey breeder house. Even greater savings could be realized if these more efficient light sources were used in turkey rearing houses.

The more energy efficient light sources emit higher light intensities per lamp unit than the incandescent lamps, and fewer light units would be necessary in a breeder house. Although the use of other light sources may save millions of dollars annually in electrical costs, these benefits may be nullified if these light sources have detrimental effects on growth, reproduction, behavior, and other traits associated with the management of turkeys.

Another approach that will improve competitiveness is to increase production on a biological unit basis. This can be accomplished by optimizing individual performance at a minimum operational cost. One area of interest involves the management of turkey breeder flocks. Current practice completely isolates the turkey breeder males from the females throughout their entire lifetime. Recent work at this station has shown that the presence of a few males in pens of breeding female Medium White turkeys significantly improved egg production over pens of females isolated from males. If this relationship holds true for the Large White turkey, significant economic benefits may be gained by the commercial turkey industry.

Objectives:

(1) To examine the effects of different light sources (sodium vapor, daylight fluorescent, and incandescent) on growth and reproductive performance of primary breeder Large White turkeys.

(2) To ascertain if light source used during the adolescent period has a subsequent effect on reproductive performance.

(3) To determine the effects of the presence or absence of the opposite sex on reproductive performance.

(4) To determine if light source or the presence of the opposite sex during the breeding season is a potential stressor.

## REVIEW OF LITERATURE

### Light and Avian Growth

One area of importance concerning the influence of light on avian growth is that of light duration. Lanson and Sturkie (1961), working with chickens, noted no differences in body weight or feed consumption due to continuous, intermittent, or flashing light treatments. Later, Buckland *et al.* (1976) showed improved growth rates in birds maintained under continuous light or 1 hour (h) light:3 h dark (1L:3D) repeated 6 times per day versus birds provided 1L:3D:13L:7D over a 24 hour period. Other studies have shown growth patterns that favor intermittent light regimes over continuous light (Buckland, 1975; Hoopaw and Goodman, 1976; McDaniel *et al.*,1977; Deaton *et al.*, 1978; Beane *et al.*, 1979; and Cherry *et al.*, 1980).

Cherry and Barwick (1962) noted that light intensities as low as 1.1 lux or as high as 107.6 lux (0.1 or 10.0 footcandles, respectively) were sufficient for growing chickens. Meanwhile, Dorminey and Nakaue (1977) found that low-intensity intermittent light was more effective than high-intensity intermittent light in stimulating growth.

### Light Spectrum and Avian Growth

Another area of concern is the effect of light spectrum on growth. In chickens, several early studies failed to find any differences due to light color on several growth traits (Barrot and Pringle, 1951; Kondra, 1961; Cherry and Barwick, 1962; and Schumaier *et al.*, 1968). On the other hand, Foss *et al.* (1967) noted accelerated and retarded growth using blue and red light, respectively, as compared to white light. In addition,

Wells (1971) noted an increase in mortality in birds reared under red light. Foss *et al.* (1972) noted significant increases in growth due to green light versus red, blue, white, and total darkness treatments, while no differences in feed consumption were observed. These findings were supported by Wabeck and Skoglund (1974), who observed superior growth using either blue or green light as opposed to red, yellow, or white light.

Photoperiod and Growth of Turkeys

Auckland (1973) reported that toms reared from 6 to 18 weeks of age under 23L:1D had higher body weights than those reared on 14 h light per day or on a step-down pattern of 1 h per week from 23 to 14 h light per day. In contrast, Ivaschenko and Alekseev (1974) noted that turkeys reared under 4, 8, 14, 18, 20, or 24 h of continuous light per day, the 4 and 8 h of daylight treatments yielded the highest body weights at 17 weeks of age. On the other hand, Buckland *et al.* (1974) found that continuous light (24 h/day) resulted in higher body weight gains than did 14 or 16 h of light per day. Buckland (1975) concluded that, in general, intermittent lighting programs are superior to continuous light programs in producing desirable growth traits, such as increased feed efficiency and body weight gain, and decreased mortality. Studies by Auckland (1978a,b) showed that 23, 14, or 8 hours of light per day or a step-down pattern (as described in Auckland, 1973) did not alter growth performance. In accordance, Hulan *et al.* (1980) noted no differences in growth rates of poults kept under 23 h light per day, total darkness, or an intermittent schedule of 4L:2D repeated 4 times per day. There appeared

to be trends for improved growth, however, under the intermittent light treatment. In contrast, Engster *et al.* (1982) reared toms and hens under either 23L:1D; 14L:10D; or 1L:3D (repeated 6 times per day) at 10.0 lux of light intensity. Although there were no differences in feed efficiency, the intermittent light program resulted in superior weight gains prior to 14 weeks of age. In support of these results, Gill and Leighton (1984) found that an intermittent lighting pattern of 2L:2D repeated 6 times per day stimulated growth when compared to a diurnal pattern of 12L:12D.

Light Intensity and Growth of Turkeys

Light intensity is another important factor to consider when growing turkeys. One study showed no differences in growth performance when either 21.5 or 64.6 lux was provided (Shoffner *et al.*, 1962), whereas another study found that 0.22 lux was superior to 30.0 lux for growth after 12 weeks of age (Touchburn *et al.*, 1970). Bacon and Touchburn (1976) showed that 0.11 lux was best for growth up to 12 weeks, and intensities of 1.1, 11.0, and 33.0 lux were superior from 12 to 22 weeks of age. Although various combinations of these intensities from 0 to 12 and 12 to 22 weeks showed no effect on growth, the highest 22-week body weight was for birds reared continuously on 11 lux. On the other hand, Berg and El Halawani (1979) reported that when toms were subjected to 2L:4D (repeated 4 times daily) and various combinations of 4.0 and 97.2 lux during the growth period, the heaviest 20-week body weight resulted in birds kept on 97.2 lux throughout the entire experiment. Proudfoot *et al.* (1979) noted that white light at 7.0 lux was superior to 0.4 lux

for improving body weight up to 14 weeks of age, but that green light at 0.4 lux yielded better results than either of the other two treatments. In accordance with the work of Bacon and Touchburn (1976), Siopes *et al.* (1983) found that with intensities of 1, 11, 110, or 220 lux, the 11 lux treatment provided the best results on feed conversion. Gill and Leighton (1984) showed that while 5.4 lux tended to benefit growth of male turkeys at an early age, 86.1 lux gave better results later in the growing period (after 12 weeks of age). An intensity of 1.1 lux was shown to have adverse effects on body weight, livability, and feed conversion by Siopes *et al.* (1984), as compared to intensities of 11, 110, and 220 lux.

Smith and Phillips (1959) found no differences in growth or feed consumption when green, yellow, orange, or red neon lights were fastened to feeders. Work by Kondra (1961) supported those findings when red, green, and white heat lamps were used for brooding. On the other hand, Proudfoot *et al.* (1979) showed that green light was superior to white light (at equal intensities) in stimulating body weight gains. Gill and Leighton (1984) found that blue light tended to stimulate growth at an early age, while white or red light yielded better results following approximately 14 weeks of age. These results were confirmed by Levenick and Leighton (1988) when intermittent (2L:2D) and diurnal (12L:12D) light treatments were used.

Prebreeder Light Restriction and Reproduction of Turkeys

It has been well-documented that the breeding season of turkeys can be modified by light environment manipulation (Albright and Thompson, 1933; Margolf *et al.*, 1947; King, 1958; Clayton and Robertson, 1960; and

Wilson *et al.*, 1967). Leighton and Shoffner (1961 a,b) showed that exposing birds to 6 or 8 h of light per day for a 2 to 4 week period in the fall resulted in increased egg production and an earlier age at first egg following photostimulation. Birds in both studies maintained on unrestricted light (14 h of light per day) showed evidence of being photorefractory when subsequently exposed to longer photoperiods. They also noted that age at first egg decreased as date of hatch increased in the fall, i.e., from September 10 to October 22. Ogasawara *et al.*, (1962) found that 6 h of restricted light per day was superior to 10 h of restricted light when a 3 week program was used prior to stimulatory lighting. They also noted that light restricted (R) to 6 h of light per day followed by stimulatory (S) light of 14 h per day resulted in higher egg production than did a 10R:20S, 6R:20S, or 10R:14S h daylength combination. Leighton and Potter (1969) found that "brownout" (0.86 lux of light intensity) versus "blackout" (0.00 lux) conditions of darkness during the preconditioning period resulted in the same level of subsequent egg production, whether the 6 h of daily light restriction was continued for 5, 9, or 10 weeks prior to stimulatory lighting. They also noted that egg production for out-of-season birds under any of the restricted light treatments was greater than that of unrestricted controls. McCartney (1971) suggested that birds performed better when lighted at 32 and 36 weeks of age as opposed to 28 weeks of age. Also, the older birds produced larger eggs and exhibited higher fertility. Jones *et al.* (1982) preconditioned breeder hens from 20 to 32 weeks of age with 8 h of either red or white light. Although feed consumption was highest for birds kept

under white light, prebreeder light color yielded no subsequent effects on egg production.

Prebreeder lighting requirements for toms have not been as extensively studied as those for hens. According to Polley *et al.* (1962), light threshold may be lower for toms than for hens. In support of this idea, Ogasawara *et al.* (1962) found that exposing toms to 20 h of light per day following 3 weeks of either 6 or 10 h days apparently caused a reduced response to stimulatory light, whereas no negative effects on hens were observed. In contrast, McGillivary and Koslin (1965) found no refractory response in toms reared under several lighting programs when they were subsequently subjected to breeder lighting. Later, Wall and Jones (1976) noted that toms maintained on 6 h lights from 8 to 22 weeks of age and subsequently exposed to 14 h days exhibited higher reproductive performance than did toms kept on natural daylight during the same "out-of-season" time (May to November). In agreement with these findings, Wilson *et al.* (1976) noted that 8 h of light daily delayed sexual maturity in toms, and that males maintained under this light treatment were unable to maintain semen production 6 to 7 weeks after maturity. Accordingly, Siopes (1981b) concluded that duration, not intensity, of lighting is the most important factor to consider when light restriction is imposed in preparation for the breeding period. Leighton and Meyer (1984) noted that restricted light (6 h per day) from 12 to 28 weeks of age resulted in higher semen concentration (without affecting ejaculate volume) than if toms were kept on continuous 12 h of light per day. In a second experiment, they found that birds subjected to natural daylength from

February to June had higher semen concentration and volume than did toms reared under 12 h of light per day during the same time period. Leighton and Jones (1984) found that toms restricted to 6 h of light per day from 12 to 30 weeks of age had higher semen volumes and concentrations during the breeding season than those restricted to 12 h days. No differences in semen volume were found due to light intensities of 10.8, 21.5, 43.0, or 86.1 lux during the adolescent period. It was noted, however, that semen volume was consistently higher for males exposed to either 43.0 or 86.1 lux of light intensity during the breeding season compared to those exposed to 10.8 or 21.5 lux of light intensity.

Photoperiod and Reproduction in Aves

It is well known that light plays a role of utmost importance in the reproduction of *Aves*. This has been documented in many species, including the English sparrow (Ringoen, 1942), the Green finch (Damste, 1947), the junco (Wolfson, 1952), the domestic duck (Benoit, 1964), the Red crossbill (Tordoff and Dawson, 1965), the White-crowned sparrow (Follet *et al.*, 1975), the Japanese Quail (Follet, 1976), the Starling (Dawson and Goldsmith, 1983), and the Harris Hawk (Bednarz, 1987). Information regarding the the optimum light environment for stimulating turkey reproduction is somewhat varied. Asmundson and Moses (1950) reported that as few as 9 h of continuous light per day could stimulate egg production, but that its onset was retarded. They found that 14 to 15 h of light per day yielded maximal results. Similar results were obtained by Leighton and Shoffner (1961a) and Garland *et al.* (1961). Ogasawara *et al.* (1962) found that 14 h of light per day yielded higher

egg production than 20 h, if birds were restricted to 6 h light per day prior to the breeding period. On the other hand, Marsden *et al.* (1966) found no differences in egg production when hens were kept on 11, 13, or 15 h light per day. In support of the findings of Brown *et al.* (1973), Bacon and Nestor (1977) exposed hens to either 14 h of continuous light or 14 1-hour light periods equally spaced within a day. Both studies reported that egg production was not affected, but feed consumption per egg favored the intermittent light regimen (Bacon and Nestor, 1977). In other studies, Bacon and Nestor (1980, 1981, 1982) reported similar results, but they noted an increase in the number of floor eggs under intermittent light programs. In contrast, Cherms (1982) noted that egg production under intermittent lighting was lower early in the production cycle but higher in the final weeks as opposed to production for birds maintained under 14 h of continuous light per day.

The daylength requirements of toms for optimum reproductive performance have also been studied. Siopes (1983) maintained breeder toms on one of the following light treatments: 15L:9D (control); 2L:11D:4L:7D; 4L:9D:4L:7D; 2L:11D:2L:9D. Males on all 3 intermittent light treatments consumed less feed and produced equal quality semen when compared to controls. Lu *et al.* (1986) used the following photoperiod and light intensity combinations on breeder males: 12L:12D at intensities of 5.4, 10.8, and 54.0 lux; and 16L:8D at intensities of 5.4, 10.8, or 54.0 lux. The 12L:12D program at 10.8 lux yielded significantly lower semen volume and percentage of males producing semen, whereas the 16L:8D photoperiod

at 10.8 lux resulted in the highest semen volume, fertility, and percentage of males in semen production.

Light Intensity and Reproduction in Turkeys

It has been reported that 21.5 lux is the minimum light intensity requirement for turkey breeder hens (Asmundson *et al.*, 1946; Garland *et al.*, 1961). In contrast, McCartney (1971) found that 16.1 lux was as effective as 32.3 lux in stimulating egg production. Nestor and Brown (1972) noted that light intensity for reproduction may be strain-specific, i.e., different strains of birds may have their own optimal light intensity. With regard to high intensity lighting, Siopes (1984a) noted no differences in fertility, hatchability, or early season egg production between intensities of 22 and 108 lux.

Information on light intensity for breeder toms is even more limited. Jones *et al.* (1977) found that males responded equally to intensities of 5.3, 43.0, or approximately 2700 lux (sunlight) in semen volume and concentration. On the other hand, Thurston *et al.* (1982) found that toms produced more semen and had higher concentrations of spermatozoa and seminal plasma protein when maintained on cool-white fluorescent bulbs (189 lux) compared to incandescent bulbs (10 lux). Cecil (1986) noted that although 6.5 or 100.0 lux had no effect on semen volume for normal-weight males, 100.0 lux tended to improve the semen concentrations of low-weight toms.

Light Sources and/or Color and Reproduction in Turkeys

Following the discovery that light could be used to modify the breeding season of domestic birds (Albright and Thompson, 1933; Warren and Scott, 1936), various studies have been performed to determine the proper light spectrum or color combinations that might maximize reproductive performance. Scott and Payne (1937) stated that turkeys are most sensitive to light of the longer visible wavelengths (red, orange, and yellow). Since then, different light sources, each with their own specific spectral characteristics, have been tested for use with breeder turkeys. In a very early study, Milby and Thompson (1945) experimented with gasoline lanterns, kerosene lanterns, natural gas lanterns, and incandescent lights. They found that hens would not respond reproductively to the light emitted by a kerosene flame. Later, Payne and McDaniel (1958) compared daylight fluorescent lights (at 15 watts) and incandescent lights (at 60 watts). They concluded that the fluorescent lamps were insufficient in maintaining high egg production, fertility, and hatchability. In contrast, Siopes (1981a) found no differences in egg production, fertility, or poult weight between incandescent and full-spectrum fluorescent light treatments, although hatchability was significantly lower for birds under fluorescent lights. Similar results were obtained by Siopes (1984 a,b) using cool-white and full-spectrum fluorescent lights, respectively. Concerning light color, Jones *et al.* (1982) found that birds responded equally in egg production to red or white light at 85 lux, and that white light, as compared to red light, at 160 lux had an adverse effect on egg production.

Presence of the Opposite Sex and Reproduction in Turkeys

To date, much of the research conducted on the effect of the presence or absence of the opposite sex on reproduction in *Aves* has involved short-term effects, such as hormonal changes. For example, elevated testosterone levels have been observed in sexually active ducks (Balthazart, 1976) and chickens (Benoff *et al.*, 1978) as compared to sexually passive controls. Also, O'Connell *et al.* (1981) reported that simple visual exposure to sexually active females induced testosterone increases in male ring doves.

The importance of the opposite sex on long-term reproduction factors has also been studied. It has been noted that the presence of cocks had no effect on egg production in chickens (Kondalov, 1975; Tarapovski, 1977; and Bhagwat, 1978). Bacon and Nestor (1977), using turkeys, found an increased rate of lay in both medium-weight (MW) and large-weight (LW) hens due to the visual and vocal presence of toms. For LW hens, they noted a decreased number of broody periods with an increased length of each broody period, but there was no influence on the number of effective days of production. In addition, LW hens in the presence of toms exhibited higher fertility as compared to isolated controls. No effect on fertility was observed in MW hens due to the presence of toms, although all hens in this study were artificially inseminated. Jones and Leighton (1987) found significant increases in egg production due to the physical presence of toms. Hens under natural mating conditions had the highest egg production, followed by hens in the visual and vocal presence of males, and hens isolated from males, respectively.

Other research has examined the effects of female presence on male reproductive performance. Fomin (1975) compared sexually active and sexually passive toms and cocks in the presence of females. Results showed that semen volume and concentration were higher for the sexually passive males. In chickens, Sochkan and Bulgia (1981) reported that males kept in sight of sexually active females had higher quality semen than did isolate males. On the other hand, Jones and Leighton (1987) found that isolated turkey males had higher semen concentration than males in the presence of females, but the latter group had a higher percentage of normal sperm than that of the isolates.

Stress and Poultry

Many studies have been conducted with chickens to evaluate the role of stress on well-being. Numerous factors have been demonstrated as stressors, including temperature extremes (Etches, 1976; Beuving and Vonder, 1978, and Arjona *et al.*, 1988), social interaction (Hall and Gross, 1975; Gross *et al.*, 1984), oviposition (Beuving, 1983), and housing environment (Craig and Adams, 1984). Any stimulus which the animal perceives as a disruptor of psychological or physiological homeostasis is a potential stressor (Williams, 1984; Freeman, 1985).

Research with chickens has shown that environmental stress may trigger physiological responses from the animal, including an increased corticosteroid level (Beuving and Vonder, 1978; Eskeland and Blom, 1979) and a change in the numbers of certain white blood cells (Gross *et al.*, 1980; Gross and Siegel, 1983). In chickens, Gross and Siegel (1983) concluded that the ratio of heterophils to lymphocytes (H/L) was a better

indicator of stress than plasma corticosteroid levels, with the ratio and the level of stress having a positive relationship. Other experiments with chickens have focused on the ability of the immune system to respond to an antigen following exposure to stressors (Gross and Colmano, 1969; Gross and Siegel, 1980). Also in chickens, Gross (1984) and Gross and Siegel (1985) noted that as stress increased, H/L ratio and resistance to bacterial infection increased, but that susceptibility to viral agents was greater.

## MATERIALS AND METHODS

### Adolescent Phase

Primary breeder stock male and female line Large White turkey eggs were hatched on May 12, 1986, and the poults were assigned to brooding pens. On July 9, 1986, when the birds were 8 weeks and 2 days old, they were reassigned to light-controlled pens by sex and placed under 12 hours of light per day at an intensity of 21.6 lux. Females were assigned to 12 pens of 27 birds each, and the males were assigned to 6 pens of 15 birds each. Four pens of females and two pens of males were placed under one of the following light source treatments: (a) sodium vapor, (b) daylight fluorescent, or (c) incandescent. Data were obtained on growth and feed efficiency on a biweekly basis through 22 weeks of age. Data were summarized and analyzed using a one-way analysis of variance within sex. The mathematical model used was $Y_{ij} = \mu + a_i + e_{ij}$ where $\mu$ represents the population mean, a represents the adolescent light source effect, and e represents the experimental error.

### Breeder Phase

At 22 weeks of age, females and males were maintained under the same light sources and light intensity as those imposed during the growing period. Artificial daylength was reduced to 6 hours of light per day to precondition the birds for subsequent exposure to stimulatory light during the breeding period.

At 33 weeks of age, males were reassigned to male holding pens and exposed to the same light sources used during the growing period. Artificial daylength was increased to 16 hours of light per day at light

intensities of either 21.6 or 86.1 lux. The experimental design was as follows:

Experimental Design

| Light source | Light intensity | |
|---|---|---|
| | Low (21.6 lux) | High (86.1 lux) |
| Sodium vapor | | |
| Daylight fluorescent | | |
| Incandescent | | |

The model for this design was $Y_{ijk} = \mu + s_i + i_j + si_{ij} + e_{ijk}$ where $\mu$ represents the population mean, s represents the breeder light source effect, i represents the effect of light source intensity, si represents the interaction between light source and light intensity, and e represents the experimental error. The design above allowed for the analysis of the male reproductive data in a separate design, since some males were then under another set of treatments, i.e., in the presence or absence of females. The other experimental design is as follows:

Experimental Design

| Breeder light source | Male treatment | |
|---|---|---|
| | With females | Isolated from females |
| Sodium vapor | | |
| Daylight fluorescent | | |
| Incandescent | | |

The model for the analysis of this is design was as follows: $Y_{ijk} = \mu + s_i + f_j + sf_{ij} + e_{ijk}$ where $\mu$ represents the population mean, s

represents the breeder light source effect, f represents the effect due to the presence of females, sf represents the interaction between light source and female presence effect, and e represents the experimental error.

Three days prior to semen collection, males that were in pens of females were removed from their pens and placed in all-male holding pens. This was done to prevent semen volume depletion due to mating or mating attempts. Semen was collected at 43, 47, 52, and 57 weeks of age, and evaluated for volume and spermatozoa concentration. Live-dead stains were performed on samples taken when birds were 52 and 57 weeks of age. Semen was aspirated into a glass pipette, and its volume measured to the nearest 0.01 ml. Semen concentration was obtained by collecting samples into microhematocrit tubes and centrifuging them. Percentage packed cell volume (PCV) was then measured using a Drummond Microhematocrit Reader. Spermatozoa numbers per ml of semen were calculated from percent PCV by using a standard curve developed at this institution. The regression equation for converting percent PCV to semen concentration is calculated by $Y = 0.293 + 0.333x$, where Y equals number of sperm ($x10^9$/ml) and x equals percent PCV. In performing live-dead stains, a small amount of semen was placed on a slide, evenly distributed, and then stained with a nigrosin-eosin vital dye (Cooper and Rowell, 1958). Slides were then slowly dried under low heat with a hair dryer, and placed in a dessicator until read. For each slide, 100 sperm were counted under oil immersion (900x) and grouped according to the following categories: (1) normal

unstained (alive), (2) normal stained (dead), (3) abnormal unstained (alive), and (4) abnormal stained (dead).

At 35 weeks of age, females were reassigned to the various light sources in a 3 X 3 factorial according to the following experimental design:

Experimental Design

| Adolescent light source | Breeder light source | | |
|---|---|---|---|
| | Sodium vapor | Daylight fluorescent | Incandescent |
| Sodium Vapor | | | |
| Daylight Fluorescent | | | |
| Incandescent | | | |

Each treatment combination consisted of three pens of six hens each. Artificial daylength was increased to 16 hours of light per day at an intensity of 53.8 lux (5 footcandles). The mathematical model for the design was $Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk}$ where $\mu$ represents the population mean, a represents the adolescent light source effect, b represents the breeder light source effect, ab represents the interaction between adolescent and breeder light sources, and e represents the experimental error.

In a second experiment, females were maintained in the presence or absence of males under the same breeder light sources used above in a 3 X 3 factorial arrangement of treatments according to the following experimental design:

Experimental Design

| Breeder light source | Female treatment | | |
|---|---|---|---|
| | Male in pen | Male in adjacent pen | Male absent |
| Sodium Vapor | | | |
| Daylight Fluorescent | | | |
| Incandescent | | | |

Each treatment combination consisted of three pens of six hens each. Artificial daylength was increased to 16 hours of light per day at an intensity of 53.8 lux (5 footcandles). The mathematical model for the design was $Y_{ijk} = \mu + s_i + m_j + sm_{ij} + e_{ijk}$ where $\mu$ represents the population mean, s represents the breeder light source effect, m represents the effect due to the presence of males, sm represents the interaction between light source and male presence effect, and e represents the experimental error. In this design, one male was assigned to each of nine pens of females. Nine adjacent pens of females were allowed visual and vocal but no physical contact with the males. Nine other pens of females were completely isolated from males (physically, visually, and audibly).

Data in both studies were obtained on days to first egg, and on egg production, fertility, and hatchability throughout the production period. Hens were artificially inseminated twice within a week at the onset of lay, and then at biweekly intervals for the next ten weeks and at weekly intervals during the final ten weeks of the production cycle. Each hen was inseminated with 0.05 ml of pooled semen diluted 1:1 with Beltsville Poultry Semen Extender. Eggs were set every two weeks, and

records of fertility and hatchability were kept. Body weight was obtained an individual basis when hens were 35, 47, and 57 weeks of age. Broodiness was determined by checking trapnests late in the afternoon and palpating nested hens for evidence of an egg in the oviduct. Any hen found with no egg in the oviduct for 3 days in a row was placed in a broody coop for 5 days, and then returned to its original pen. Only hens meeting these criteria were considered as broody. Egg weights and specific gravities were recorded twice, when the hens were 42 and 50 weeks of age. Eggs were collected each day over a ten day period or until five eggs per hen were obtained. Egg weights were determined by weighing them on an electric top-loading balance accurate to the nearest 0.1 gram. Specific gravities, as an indirect measure of eggshell quality (Foster and Weatherup, 1979; Opengart *et al.*, 1987), were determined by dipping eggs in a series of saline solutions ranging from 1.060 to 1.100 specific gravity units at 0.005 intervals. Eggs that first floated in a specific gravity solution were designated as having that specific gravity.

At 55 weeks of age, 1.0 ml of blood from randomly selected birds in each treatment was collected into 2.0 ml tubes containing Sequester-Sol (Cambridge Chemical Products, Inc., Fort Lauderdale, Fl) as an anticoagulant. Samples of 0.2 ml were placed on slides and evenly distributed across the slide with a Corning LARC Spinner. Cells were dried and stained according to Lucas and Jamroz (1961). All slides were examined under oil immersion at 900x. The first 100 heterophils and/or lymphocytes observed were counted. Heterophil-to-lymphocyte (H/L) ratios were calculated from these counts.

The same birds (at the time of blood sampling for H/L ratios) received 0.1 ml injections of a 0.25 % solution of equine red blood cells in saline. Six days later, 1.0 ml blood was collected into 2.0 ml tubes, again using Sequester-Sol as an anticoagulant. Samples of 0.2 ml were then evaluated for immune response via a hemagglutination test (Wegmann and Smithies, 1966).

All data were analyzed by the Analysis of Variance procedure at a significance level of $\alpha = 0.05$. When significant treatment effects were noted, differences between treatments were evaluated by Duncan's Multiple Range Test (Duncan, 1955). All percentage data were transformed to the arcsine$\sqrt{\text{percentage}}$ prior to analyses.

## EXPERIMENTAL RESULTS

### Light Sources and Growth

Body weights of males and females by light source treatment are presented in Table 1. Male body weight was unaffected by light treatment throughout the entire growing period, except at 12 weeks of age. Hens reared under sodium vapor (SV) lights showed significantly higher body weights at 18, 20, and 22 weeks of age than females under the either the fluorescent (FL) or incandescent (IN) light treatments ($p \leq .05$).

Body weight gains of males and females are summarized in Tables 2 and 3, respectively. As compared to the SV or IN light treatments, male body weight gains were significantly lower from 10 to 12 weeks under FL lights (Table 2). Female body weight gains (Table 3) were significantly higher under the FL treatment only during 8 to 10 weeks. From 16 to 18 weeks, FL light had a depressing effect on female body weight gain. No effects due to light source treatment were obtained from 18 to 22 weeks of age.

Cumulative feed efficiency for both males and females was unaffected by light source treatment during any time period (Tables 4 and 5).

### Breeder Phase-Effects of Adolescent and Breeder Light Sources on Females

Female body weight data by adolescent and breeder light source treatment are summarized in Table 6. Hens reared under SV lights had significantly heavier body weights than those reared under IN light only

Table 1. Body weight of male and female turkeys from 8 to 22 weeks of age by light source treatment

| Sex | Light Source | Body weight (kg) by age (weeks)[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 10 | 12 | 14[2] | 16 | 18 | 20 | 22 |
| Males | Sodium Vap. | 3.20[a] | 4.65[a] | 6.19[a] | - | 9.05[a] | 10.60[a] | 11.64[a] | 12.58[a] |
| | Fluor | 3.08[a] | 4.46[a] | 5.76[b] | - | 8.75[a] | 10.35[a] | 11.74[a] | 13.65[a] |
| | Incand. | 3.12[a] | 4.53[a] | 6.14[a] | - | 9.17[a] | 10.39[a] | 11.94[a] | 13.01[a] |
| | Pooled SEM[3] | ±0.068 | ±0.093 | ±0.131 | - | ±0.233 | ±0.301 | ±0.358 | ±0.396 |
| Females | Sodium Vap. | 2.48[a] | 3.31[a] | 4.44[a] | 5.48[a] | 6.35[a] | 7.10[a] | 7.77[a] | 8.31[a] |
| | Fluor. | 2.47[a] | 3.38[a] | 4.39[a] | 5.43[a] | 6.28[a] | 6.95[b] | 7.60[b] | 8.11[b] |
| | Incand. | 2.47[a] | 3.33[a] | 4.36[a] | 5.31[b] | 6.13[b] | 6.90[b] | 7.59[b] | 8.14[b] |
| | Pooled SEM[3] | ±0.021 | ±0.025 | ±0.030 | ±0.035 | ±0.041 | ±0.045 | ±0.051 | ±0.055 |

[1] Means within sex and weeks with different superscripts are significantly different from each other ($P \leq .05$).

[2] Body weights of males were not obtained at 14 weeks of age.

[3] Standard error of the mean.

Table 2. Body weight gains of male turkeys from 8 to 22 weeks of age by light source treatment

| Sex | Light Source | Body weight gain (kg) by age (weeks)[1] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 8-10 | 10-12 | 12-16[2] | 16-18 | 18-20 | 20-22 |
| Males | Sodium Vap. | 1.43[a] | 1.55[a] | 2.81[a] | 1.32[a] | 1.04[a] | 0.79[a] |
| | Fluor. | 1.38[a] | 1.32[b] | 2.94[a] | 1.36[a] | 1.16[a] | 1.43[a] |
| | Incand. | 1.41[a] | 1.62[a] | 2.95[a] | 1.13[a] | 1.36[a] | 1.07[a] |
| | Pooled SEM[3] | ±0.057 | ±0.068 | ±0.170 | ±0.160 | ±0.151 | ±0.205 |

[1] Means within sex and weeks with different superscripts are significantly different from each other ($P \leq .05$).

[2] Male body weights not taken at 14 weeks of age.

[3] Standard error of the mean.

Table 3. Body weight gains of female turkeys from 8 to 22 weeks of age by light source treatment

| Sex | Light Source | Body weight gain (kg) by age (weeks)[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 8-10 | 10-12 | 12-14 | 14-16 | 16-18 | 18-20 | 20-22 |
| Females | Sodium Vap. | 0.83[a] | 1.13[a] | 1.04[a] | 0.87[a] | 0.75[a] | 0.67[a] | 0.54[a] |
| | Fluor. | 0.92[b] | 1.01[b] | 1.03[a] | 0.85[a] | 0.67[b] | 0.65[a] | 0.52[a] |
| | Incand. | 0.86[a] | 1.04[b] | 0.96[b] | 0.82[a] | 0.75[a] | 0.69[a] | 0.55[a] |
| | Pooled SEM[2] | ±0.017 | ±0.014 | ±0.015 | ±0.019 | ±0.15 | ±0.021 | ±0.021 |

[1] Means within sex and weeks with different superscripts are significantly different from each other ($P \leq .05$).

[2] Standard error of the mean.

Table 4. Cumulative feed efficiency[1] of male turkeys from 10 to 22 weeks of age by light source treatment

| Sex | Light Source | Feed efficiency by age (weeks) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-10 | 0-12 | 0-16[2] | 0-18 | 0-20 | 0-22 |
| Males | Sodium Vap. | 0.55 | 0.50 | 0.42 | 0.41 | 0.37 | 0.35 |
| | Fluor. | 0.54 | 0.49 | 0.42 | 0.41 | 0.39 | 0.37 |
| | Incand. | 0.54 | 0.51 | 0.44 | 0.40 | 0.39 | 0.36 |
| | Pooled SEM[3,4] | ±0.004 | ±0.004 | ±0.010 | ±0.005 | ±0.006 | ±0.010 |

[1] Feed efficiency = kg of body weight gain/kg feed consumed.

[2] Male body weights not taken at 14 weeks of age.

[3] Standard error of the mean.

[4] No significant differences among treatments.

Table 5. Cumulative feed efficiency[1] of female turkeys from 10 to 22 weeks of age by light source treatment

| Sex | Light Source | Feed Efficiency By Age (weeks) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0-10 | 0-12 | 0-14 | 0-16 | 0-18 | 0-20 | 0-22 |
| Females | Sodium Vap. | 0.46 | 0.44 | 0.41 | 0.38 | 0.35 | 0.32 | 0.29 |
| | Fluor. | 0.47 | 0.44 | 0.41 | 0.37 | 0.34 | 0.31 | 0.30 |
| | Incand. | 0.46 | 0.43 | 0.40 | 0.36 | 0.34 | 0.31 | 0.29 |
| | Pooled SEM[2,3] | ±0.011 | ±0.005 | ±0.004 | ±0.004 | ±0.003 | ±0.003 | ±0.003 |

[1] Feed efficiency = kg of body weight gain/kg feed consumed.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 6. Body weight of female turkeys at 35, 47 and 57 weeks of age by adolescent and breeder light source treatment

| Time Period | Light Source | Body weight (kg) By age[1] | | |
|---|---|---|---|---|
| | | 35 wks | 47 wks | 57 wks |
| Adolescent | Sodium Vap. | 10.9[a] | 9.9[a] | 9.7[a] |
| | Fluor. | 10.9[a] | 9.8[a,b] | 9.5[a] |
| | Incand. | 10.8[a] | 9.6[b] | 9.5[a] |
| | Pooled SEM[2] | ±0.090 | ±0.092 | ±0.119 |
| Breeder | Sodium Vap. | 10.8[a] | 9.7[a] | 9.5[a] |
| | Fluor. | 10.8[a] | 9.7[a] | 9.5[a] |
| | Incand. | 11.0[a] | 9.9[a] | 9.7[a] |
| | Pooled SEM[2] | ±0.090 | ±0.092 | ±0.119 |
| Experimental Mean | | 10.9 | 9.7 | 9.5 |

[1] Means within time period and age with different superscripts are significantly different from each other ($P \leq .05$).

[2] Standard error of the mean.

at 47 weeks of age. No other significant differences in body weight were found.

Egg production by adolescent and breeder light sources are presented in Table 7. Hen-housed and hen-day egg production were unaffected by adolescent light source. There were no significant differences in total egg production due to breeder light source treatment, however birds exposed to IN light produced significantly fewer eggs during the first half of the breeder season in both hen-housed and hen-day egg production. Hen-day egg production by breeder light source treatment is shown graphically in Figure 1.

Fertility and hatchability were unaffected by either adolescent or breeder light source treatment (Table 8).

There were no significant differences in days to first egg, egg weight, or egg specific gravity due to adolescent or breeder light source treatment (Table 9).

Heterophil-to-lymphocyte (H/L) ratio and antibody titer, as indicators of stress, were both unaffected by either adolescent or breeder light source treatments (Table 10).

## Breeder Phase-Effects of Light Sources and Light Intensity on Males

There were no significant differences in semen volume due to light source or light intensity (Table 11). Percent packed cell volume (PCV) was also unaffected by light source or light intensity during the breeder period (Table 12).

Table 7. Egg production[1] by adolescent and breeder light source treatment

| Time Period | Light Source | Egg production by weeks[2,3] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hen-housed | | | Hen-day | | |
| | | 1-10 | 11-20 | 1-20 | 1-10 | 11-20 | 1-20 |
| Adolescent | Sodium Vap. | 43[a] | 24[a] | 67[a] | 43[a] | 25[a] | 68[a] |
| | Fluor. | 44[a] | 28[a] | 72[a] | 44[a] | 28[a] | 72[a] |
| | Incand. | 41[a] | 25[a] | 67[a] | 42[a] | 26[a] | 69[a] |
| | Pooled SEM[4] | ±0.9 | ±2.1 | ±2.7 | ±0.8 | ±2.0 | ±2.5 |
| Breeder | Sodium Vap. | 43[a] | 26[a] | 70[a] | 43[a,b] | 26[a] | 70[a] |
| | Fluor. | 44[a] | 28[a] | 72[a] | 44[a] | 28[a] | 72[a] |
| | Incand. | 40[b] | 24[a] | 64[a] | 41[b] | 25[a] | 66[a] |
| | Pooled SEM[4] | ±0.9 | ±2.1 | ±2.7 | ±0.8 | ±2.0 | ±2.5 |
| Experimental Mean | | 43 | 26 | 68 | 43 | 26 | 69 |

[1] Average number of eggs produced per hen.

[2] Weeks following initiation of lay.

[3] Means within weeks and treatment with different superscripts are significantly different from each other ($P \leq .05$).

[4] Standard error of the mean.

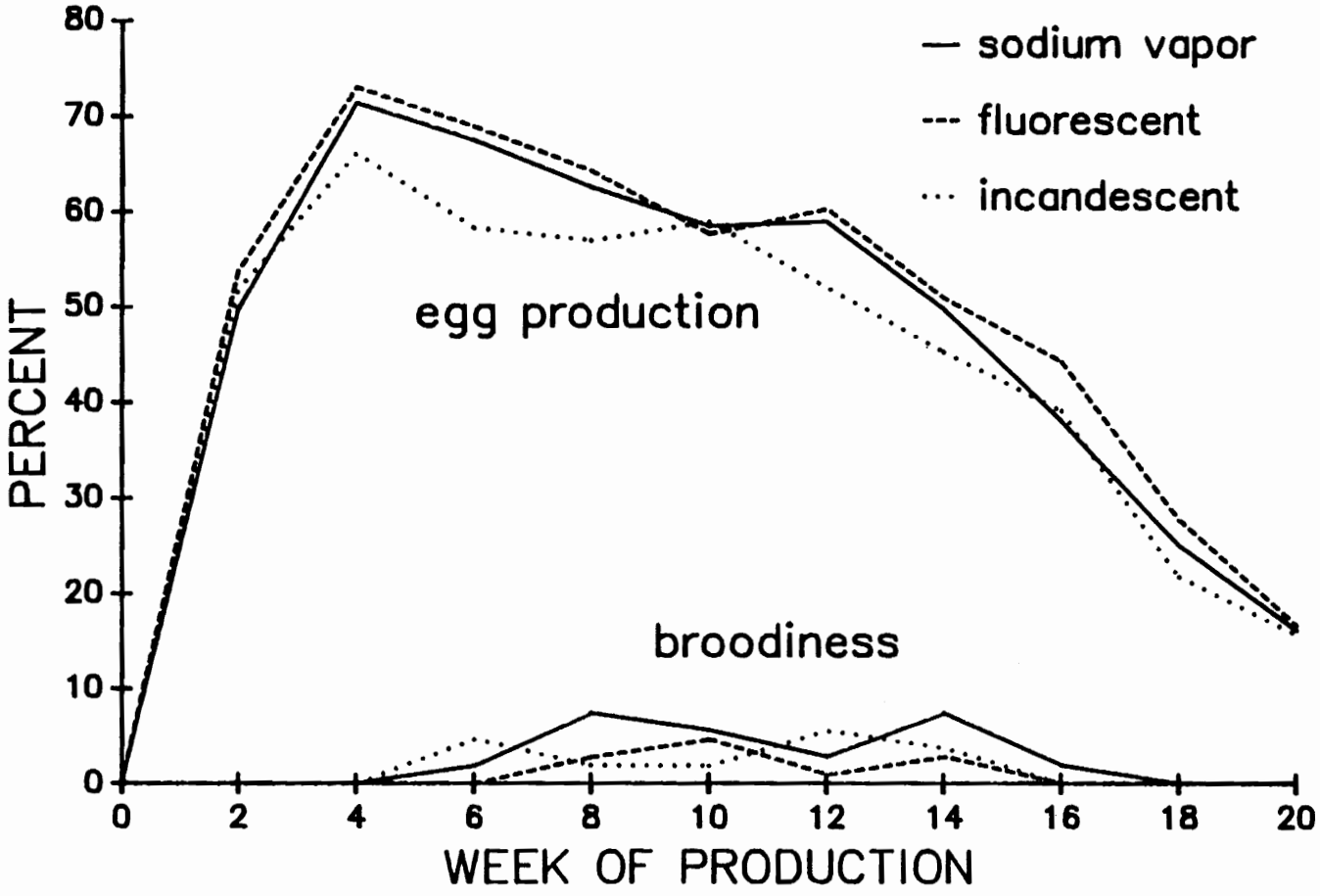


Figure 1. Hen-day egg production and broodiness by breeder light source

Table 8. Fertility and hatchability by adolescent and breeder light source treatment

| | | Fertility and hatchability by hatches (weeks)[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-10 | | | 11-20 | | | 2-20 | | |
| Time Period | Light Source | %F[2] | %H[3] | %HF[4] | %F | %H | %HF | %F | %H | %HF |
| Adolescent | Sodium Vap. | 81.4 | 70.2 | 86.5 | 76.8 | 61.4 | 80.2 | 79.8 | 67.1 | 84.2 |
| | Fluor. | 81.1 | 69.2 | 85.2 | 78.8 | 62.2 | 79.0 | 80.2 | 66.4 | 82.7 |
| | Incand. | 85.2 | 72.6 | 85.3 | 83.1 | 69.4 | 83.3 | 84.2 | 71.1 | 84.4 |
| | Pooled SEM[5,6] | ±2.57 | ±2.47 | ±1.38 | ±2.73 | ±2.95 | ±2.37 | ±2.33 | ±2.15 | ±1.45 |
| Breeder | Sodium Vap. | 84.2 | 72.3 | 85.9 | 78.3 | 65.0 | 82.8 | 82.0 | 69.3 | 84.5 |
| | Fluor. | 82.2 | 70.6 | 85.8 | 80.9 | 65.2 | 80.6 | 81.7 | 68.4 | 83.7 |
| | Incand. | 81.2 | 69.1 | 85.2 | 79.5 | 62.9 | 79.1 | 80.5 | 66.8 | 83.0 |
| | Pooled SEM[5,6] | ±2.57 | ±2.47 | ±1.38 | ±2.73 | ±2.95 | ±2.37 | ±2.33 | ±2.15 | ±1.45 |
| Experimental Mean | | 82.5 | 70.7 | 85.6 | 79.6 | 64.4 | 80.8 | 81.4 | 68.2 | 83.8 |

[1] Hatch #1 omitted because some eggs were laid prior to insemination.

[2] Percent fertile of eggs set.

[3] Percent hatch of eggs set.

[4] Percent hatch of fertile eggs.

[5] Standard error of the mean.

[6] No significant differences among treatments.

Table 9. Days to first egg, egg weight, and egg specific gravity by adolescent and breeder light source treatment

| Time period | Light source | Days to first egg[1] | Egg weight by age | | Egg specific gravity by age | |
|---|---|---|---|---|---|---|
| | | | 42 wks | 50 wks | 42 wks | 50 wks |
| Adolescent | Sodium Vap. | 16.1 | 91.6 | 93.9 | 1.078 | 1.076 |
| | Fluor. | 16.2 | 91.0 | 94.3 | 1.078 | 1.076 |
| | Incand. | 16.6 | 92.2 | 95.2 | 1.079 | 1.075 |
| | Pooled SEM[2,3] | ±0.037 | ±0.088 | ±1.11 | ±0.0006 | ±0.0008 |
| Breeder | Sodium Vap. | 16.2 | 91.9 | 94.5 | 1.078 | 1.076 |
| | Fluor. | 16.6 | 91.8 | 93.8 | 1.078 | 1.076 |
| | Incand. | 16.2 | 91.1 | 95.2 | 1.078 | 1.075 |
| | Pooled SEM[2,3] | ±0.037 | ±0.088 | ±1.11 | ±0.0006 | ±0.0008 |
| Experimental Mean | | 16.3 | 91.6 | 94.5 | 1.078 | 1.076 |

[1] Following exposure to 16h light/day.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 10. Immune response of female turkeys by adolescent and breeder light source treatment

| Time period | Light source | Immune response | |
|---|---|---|---|
| | | H/L ratio | Antibody titer[1] |
| Adolescent | Sodium Vap. | 1.1 | 6.3 |
| | Fluor. | 1.1 | 5.9 |
| | Incand. | 1.1 | 6.9 |
| | Pooled SEM[2,3] | ±0.10 | ±0.46 |
| Breeder | Sodium Vap. | 1.0 | 5.9 |
| | Fluor. | 1.2 | 6.2 |
| | Incand. | 1.1 | 6.9 |
| | Pooled SEM[2,3] | ±0.10 | ±0.46 |
| Experimental Mean | | 1.1 | 6.4 |

[1] Values represent the $\log_2$ of the reciprocal of the last serial dilution at which hemagglutination occurred.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 11. Semen volume by breeder light source and light intensity

| Treatment | | Semen volume (ml) by age | | | |
|---|---|---|---|---|---|
| | | 43 wks | 47 wks | 52 wks | 57 wks |
| Light source | Sodium Vap. | 0.40 | 0.36 | 0.29 | 0.30 |
| | Fluor. | 0.41 | 0.36 | 0.34 | 0.22 |
| | Incand. | 0.31 | 0.36 | 0.32 | 0.20 |
| | Pooled SEM[1,2] | ±0.033 | ±0.043 | ±0.046 | ±0.045 |
| Light Intensity (lux) | 21.6 | 0.35 | 0.35 | 0.31 | 0.18 |
| | 86.1 | 0.39 | 0.36 | 0.33 | 0.29 |
| | Pooled SEM[1,2] | ±0.027 | ±0.035 | ±0.037 | ±0.037 |
| Experimental Mean | | 0.37 | 0.36 | 0.32 | 0.24 |

[1] Standard error of the mean.

[2] No significant differences among treatments.

Table 12. Semen packed cell volume by breeder light source and light intensity

| Treatment | | Packed cell volume (%) by age | | | |
|---|---|---|---|---|---|
| | | 43 wks | 47 wks | 52 wks | 57 wks |
| Light source | Sodium Vap. | 25.9 | 26.9 | 25.9 | 24.3 |
| | Fluor. | 28.0 | 24.6 | 25.9 | 20.0 |
| | Incand. | 25.3 | 22.5 | 26.5 | 27.0 |
| | Pooled SEM[1,2] | ±1.89 | ±1.42 | ±0.94 | ±1.91 |
| Light Intensity (lux) | 21.6 | 26.4 | 24.4 | 25.9 | 22.3 |
| | 86.1 | 26.4 | 25.0 | 26.4 | 25.6 |
| | Pooled SEM[1,2] | ±1.54 | ±1.16 | ±0.76 | ±1.55 |
| Experimental Mean | | 26.4 | 24.7 | 26.1 | 24.1 |

[1] Standard error of the mean.

[2] No significant differences among treatments.

Semen quality was unaffected by breeder light source at 52 weeks of age. Percent normal stained sperm, however, was significantly lower for toms exposed to 86.1 lux of light intensity. At 57 weeks of age, no differences due to light intensity were obtained, but toms under FL light had a significantly lower percentage of normal live sperm and a higher percentage of abnormal dead sperm than did those under either SV or IN lights (Table 13).

Heterophil/lymphocyte ratio and antibody titer were unaffected by either light source or light intensity (Table 14).

## Breeder Phase-Effects of Presence of the Opposite Sex and Breeder Light Sources on Females

At 57 weeks of age, body weight was significantly lower for females isolated from males. Breeder light source treatment did not alter body weight (Table 15).

Hen-housed production was unaffected by the presence of males throughout the breeder period (Table 16). Hen-day egg production was significantly higher for hens in the presence of males, followed by hens adjacent to males and hens isolated from males, respectively. This is illustrated graphically in Figure 2. There was a significant ($p \leq .05$) breeder light source by female treatment interaction on both hen-housed and hen-day egg production (Tables 17 and 18, respectively). Hens under SV and FL lights laid numerically more eggs than those under IN light when a male was actually in the pen or in the adjacent pen.

Table 13. Percent live-dead, normal and abnormal sperm in semen of male turkeys 52 and 57 weeks of age by breeder light source and light intensity

| Treatment | | Classes (%) at 52 wks of age[1] | | | | Classes (%) at 57 wks of age | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NU[2] | NS[3] | AU[4] | AS[5] | NU | NS | AU | AS |
| Light source | Sodium Vap. | 92.2[a] | 3.4[a] | 3.2[a] | 1.2[a] | 80.1[a] | 13.0[a] | 3.7[a] | 3.3[a] |
| | Fluor. | 90.6[a] | 4.5[a] | 3.9[a] | 0.9[a] | 69.6[b] | 20.9[a] | 3.4[a] | 6.2[b] |
| | Incand. | 91.1[a] | 3.9[a] | 3.1[a] | 1.8[a] | 79.4[a] | 15.3[a] | 2.1[a] | 3.2[a] |
| | Pooled SEM[6] | ±0.79 | ±0.55 | ±0.60 | ±0.33 | ±3.00 | ±2.33 | ±0.69 | ±0.78 |
| Light Intensity (lux) | 21.6 | 90.5[a] | 4.8[b] | 3.1[a] | 1.6[a] | 75.1[a] | 16.5[a] | 4.0[a] | 4.5[a] |
| | 86.1 | 91.9[a] | 3.3[a] | 3.7[a] | 1.1[a] | 77.3[a] | 16.3[a] | 2.4[a] | 4.0[a] |
| | Pooled SEM[6] | ±0.65 | ±0.45 | ±0.49 | ±0.27 | ±2.48 | ±3.70 | ±0.57 | ±0.65 |
| Experimental Mean | | 91.3 | 3.9 | 3.4 | 1.3 | 76.4 | 16.4 | 3.0 | 4.2 |

[1] Means within class and treatment with different superscripts are significantly different from each other ($P \leq .05$).

[2] Normal unstained.

[3] Normal stained.

[4] Abnormal unstained.

[5] Abnormal stained.

[6] Standard error of the mean.

Table 14. Immune response of male turkeys by breeder light source and light intensity

| Treatment | | Immune response | |
|---|---|---|---|
| | | H/L ratio | Antibody titer[1] |
| Light source | Sodium Vap. | 1.0 | 6.3 |
| | Fluor. | 1.2 | 5.8 |
| | Incand. | 1.1 | 7.4 |
| | Pooled SEM[2,3] | ±0.21 | ±0.45 |
| Light Intensity (lux) | 21.6 | 1.0 | 6.6 |
| | 86.1 | 1.2 | 6.5 |
| | Pooled SEM[2,3] | ±0.18 | ±0.45 |
| Experimental Mean | | 1.1 | 6.6 |

[1] Values represent the $\log_2$ of the reciprocal of the last serial dilution at which hemagglutination occurred.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 15. Body weight of female turkeys at 35, 47 and 57 weeks of age by female treatment and breeder light source treatment

| Treatment | | Body weight (kg) by age[1] | | |
|---|---|---|---|---|
| | | 35 wks | 47 wks | 57 wks |
| Female Treatment | Male in pen | 11.0[a] | 9.8[a] | 9.7[a] |
| | Male in adjacent pen | 10.9[a] | 9.8[a] | 9.6[a] |
| | Male absent | 10.7[a] | 9.6[a] | 9.3[b] |
| | Pooled SEM[2] | ±0.067 | ±0.090 | ±0.084 |
| Breeder Light Source | Sodium Vap. | 10.8[a] | 9.7[a] | 9.5[a] |
| | Fluor. | 10.8[a] | 9.7[a] | 9.5[a] |
| | Incand. | 11.0[a] | 9.8[a] | 9.6[a] |
| | Pooled SEM[2] | ±0.067 | ±0.090 | ±0.084 |
| Experimental Mean | | 10.9 | 9.7 | 9.5 |

[1] Means within treatment and age with different superscripts are significantly different from each other ($P \leq .05$).

[2] Standard error of the mean.

Table 16. Egg production[1] by female treatment and breeder light source treatment

| Treatment | | Egg production by weeks[2,3] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hen-housed | | | Hen-day | | |
| | | 1-10 | 11-20 | 1-20 | 1-10 | 11-20 | 1-20 |
| Female Treatment | Male in pen | 43[a] | 28[a] | 70[a] | 44[a] | 29[a] | 74[a] |
| | Male in adjacent pen | 42[a] | 27[a] | 69[a] | 42[a] | 27[a] | 69[a,b] |
| | Male absent | 42[a] | 23[a] | 65[a] | 42[a] | 23[a] | 65[b] |
| | Pooled SEM[4] | ±0.9 | ±1.7 | ±2.0 | ±0.8 | ±1.6 | ±1.7 |
| Breeder Light Source | Sodium Vap. | 43[a] | 26[a] | 70[a] | 43[a] | 26[a] | 70[a] |
| | Fluor. | 44[a] | 28[a] | 72[a] | 44[a] | 28[a] | 72[a] |
| | Incand. | 39[b] | 23[a] | 62[b] | 41[b] | 25[a] | 66[a] |
| | Pooled SEM[4] | ±0.9 | ±1.7 | ±2.0 | ±0.8 | ±1.6 | ±1.7 |
| Experimental Mean | | 42 | 26 | 68 | 43 | 26 | 69 |

[1] Average number of eggs produced by hen.

[2] Weeks following initiation of lay.

[3] Means within weeks and treatment with different superscripts are significantly different from each other ($P \leq .05$).

[4] Standard error of the mean.

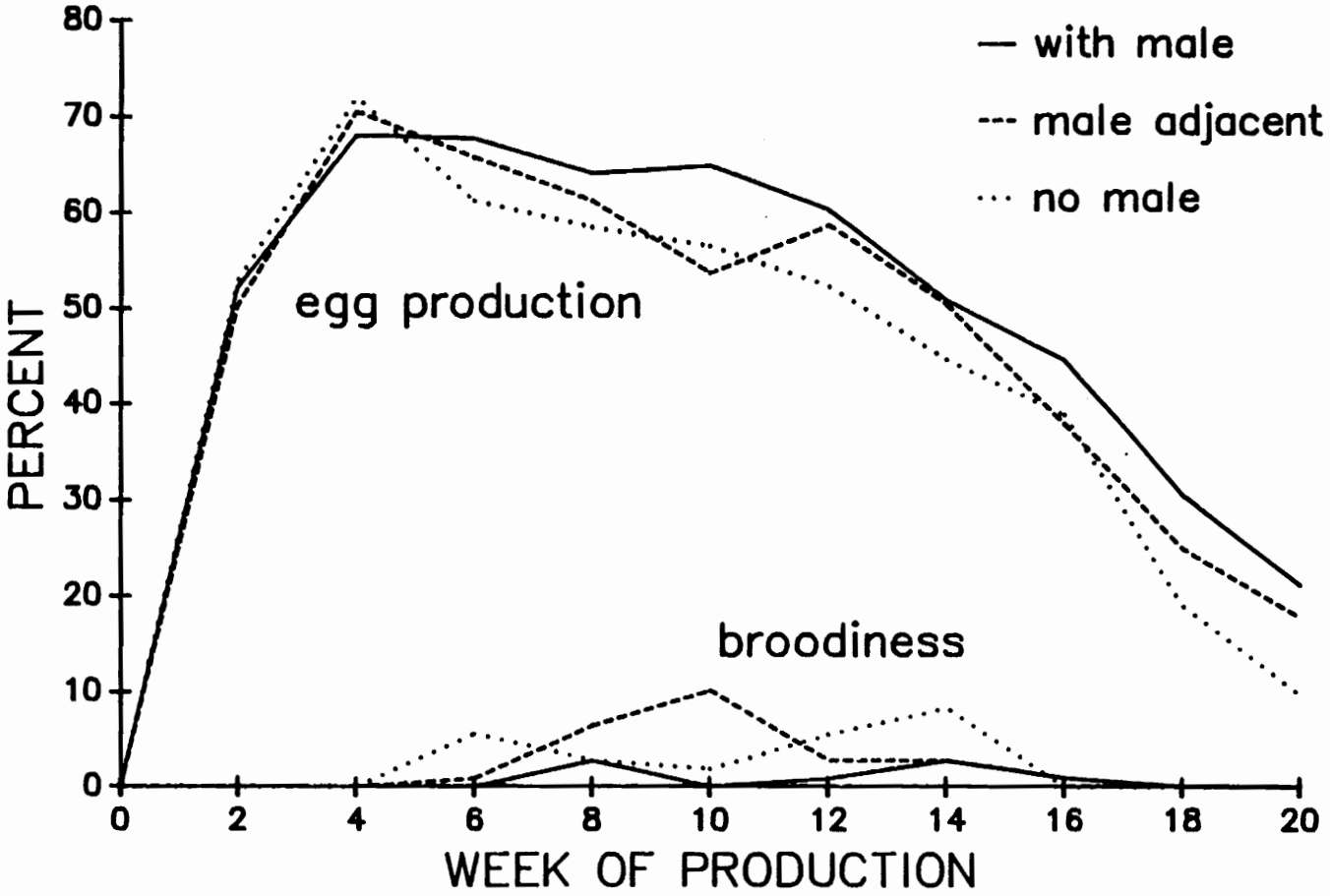


Figure 2. Hen–day egg production and broodiness by female treatment

Table 17. Interaction[1] table of breeder light source and female treatment on hen-housed egg production[2]

| Breeder Light Source | Female treatment | | | Mean |
|---|---|---|---|---|
| | With male | Male in adj. pen | No male | |
| Sodium Vapor | 79.4 | 70.1 | 59.7 | 69.7 |
| Fluorescent | 72.7 | 70.5 | 72.6 | 71.9 |
| Incandescent | 59.3 | 65.4 | 62.3 | 62.3 |
| Mean | 70.5 | 68.7 | 64.9 | 68.0 |

[1] ($P \leq .05$).

[2] Cumulatively (weeks 1-20).

Table 18. Interaction[1] table of breeder light source and female treatment on hen-day egg production[2]

| Breeder Light Source | Female treatment | | | |
|---|---|---|---|---|
| | With male | Male in adj. pen | No male | Mean |
| Sodium Vapor | 79.4 | 70.1 | 59.7 | 69.7 |
| Fluorescent | 72.7 | 70.5 | 72.6 | 71.9 |
| Incandescent | 68.3 | 65.4 | 64.0 | 65.9 |
| Mean | 73.5 | 68.7 | 65.4 | 69.2 |

[1] ($P \leq .05$).

[2] Cumulatively (weeks 1-20).

When isolated from males, hens under FL lights laid the most eggs, followed by those under IN and SV lights, respectively.

No significant differences in fertility, hatchability, or hatch of fertile eggs were noted due to the presence or absence of males or among light source treatments (Table 19).

No differences in days to first egg, egg weight, or egg specific gravity due to the presence or absence of males or exposure to various light sources were obtained (Table 20).

Neither H/L ratios nor antibody titers were significantly affected by the presence or absence of males (Table 21).

### Breeder Phase-Effects of Presence of the Opposite Sex and Breeder Light Sources on Males

Semen volume was unaffected by the presence of females or among light source treatments (Table 22).

PCV was unaffected by the presence of females (Table 23), but was significantly lower in males maintained under SV lights at 52 weeks of age.

No significant differences in semen quality were obtained between males in the presence of or isolated from females (Table 24).

The presence of females had no significant effect on H/L ratios or antibody titers of males utilized in these studies (Table 25).

Table 19. Fertility and hatchability by female treatment and breeder light source treatment

| Treatment | | Fertility and hatchability by hatches (weeks)[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-10 | | | 11-20 | | | 2-20 | | |
| | | %F[2] | %H[3] | %HF[4] | %F | %H | %HF | %F | %H | %HF |
| Female Treatment | Male in pen | 84.7 | 72.7 | 85.8 | 82.2 | 65.7 | 80.1 | 83.5 | 69.7 | 83.5 |
| | Male in adjacent pen | 81.3 | 69.4 | 85.3 | 78.7 | 63.0 | 80.1 | 80.2 | 66.8 | 83.2 |
| | Male absent | 82.8 | 70.4 | 85.0 | 78.3 | 64.6 | 82.3 | 81.4 | 68.4 | 84.0 |
| | Pooled SEM[5,6] | ± 2.20 | ± 2.30 | ± 1.31 | ± 2.79 | ± 3.31 | ± 2.34 | ± 2.16 | ± 2.23 | ± 1.37 |
| Breeder Light Source | Sodium Vap. | 84.2 | 72.3 | 85.9 | 78.3 | 65.0 | 82.8 | 82.0 | 69.3 | 84.5 |
| | Fluor. | 82.2 | 70.6 | 85.8 | 80.9 | 65.2 | 80.6 | 81.7 | 68.4 | 83.7 |
| | Incand. | 82.4 | 69.5 | 84.3 | 79.9 | 63.2 | 79.0 | 81.4 | 67.2 | 82.5 |
| | Pooled SEM[5,6] | ± 2.20 | ± 2.30 | ± 1.31 | ± 2.79 | ± 3.31 | ± 2.34 | ± 2.16 | ± 2.23 | ± 1.37 |
| Experimental Mean | | 82.9 | 70.8 | 85.3 | 79.7 | 64.5 | 80.8 | 81.7 | 68.3 | 83.6 |

[1] Hatch #1 omitted because some eggs were laid prior to insemination.

[2] Percent fertile of eggs set.

[3] Percent hatch of eggs set.

[4] Percent hatch of fertile eggs.

[5] Standard error of the mean.

[6] No significant differences among treatments.

Table 20. Days to first egg, egg weight, and egg specific gravity by female treatment and breeder light source treatment

| Treatment | | Days to first egg[1] | Egg weight by age | | Egg specific gravity by age | |
|---|---|---|---|---|---|---|
| | | | 42 wks | 50 wks | 42 wks | 50 wks |
| Female | Male in pen | 16.3 | 91.2 | 95.9 | 1.078 | 1.076 |
| Treatment | Male in adjacent pen | 16.1 | 91.7 | 93.4 | 1.078 | 1.075 |
| | Male absent | 16.7 | 91.3 | 93.9 | 1.078 | 1.076 |
| | Pooled SEM[2,3] | ±0.31 | ±0.85 | ±0.98 | ±0.0006 | ±0.0007 |
| Breeder | Sodium Vap. | 16.2 | 91.9 | 94.5 | 1.078 | 1.075 |
| Light Source | Fluor. | 16.6 | 91.8 | 93.8 | 1.078 | 1.076 |
| | Incand. | 16.3 | 90.4 | 94.9 | 1.078 | 1.076 |
| | Pooled SEM[2,3] | ±0.31 | ±0.85 | ±0.98 | ±0.0006 | ±0.0007 |
| Experimental Mean | | 16.4 | 91.4 | 94.4 | 1.078 | 1.076 |

[1] Following exposure to 16 hours of light per day.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 21. Immune response of female turkeys by female treatment and breeder light source treatment

| Treatment | | Immune response | |
|---|---|---|---|
| | | H/L ratio | Antibody titer[1] |
| Female | Male in pen | 1.2 | 5.9 |
| Treatment Source | Male in adjacent pen | 1.1 | 6.2 |
| | Male absent | 1.1 | 7.1 |
| | Pooled SEM[2,3] | ±0.10 | ±0.46 |
| Breeder | Sodium Vap. | 1.0 | 5.9 |
| Light Source | Fluor. | 1.2 | 6.2 |
| | Incand. | 1.1 | 7.1 |
| | Pooled SEM[2,3] | ±0.10 | ±0.46 |
| Experimental Mean | | 1.1 | 6.4 |

[1] Values represent the $\log_2$ of the reciprocal of the last serial dilution at which hemagglutination occurred.

[2] Standard error of the mean.

[3] No significant differences among treatments.

Table 22. Semen volume by male treatment and breeder light source treatment

| Treatment | | Semen volume (ml) by age | | | |
|---|---|---|---|---|---|
| | | 43 wks | 47 wks | 52 wks | 57 wks |
| Male | With females | 0.34 | 0.26 | 0.31 | 0.24 |
| Treatment | Isolated from females | 0.34 | 0.32 | 0.31 | 0.19 |
| | Pooled SEM[1,2] | ±0.038 | ±0.045 | ±0.039 | ±0.038 |
| Breeder | Sodium Vap. | 0.29 | 0.22 | 0.25 | 0.23 |
| Light Source | Fluor. | 0.40 | 0.35 | 0.33 | 0.13 |
| | Incand. | 0.33 | 0.31 | 0.35 | 0.28 |
| | Pooled SEM[1,2] | ±0.047 | ±0.055 | ±0.048 | ±0.047 |
| Experimental Mean | | 0.34 | 0.29 | 0.31 | 0.22 |

[1] Standard error of the mean.

[2] No significant differences among treatments.

Table 23. Semen packed cell volume by male treatment and breeder light source treatment[1]

| Treatment | | Packed cell volume (%) by age | | | |
|---|---|---|---|---|---|
| | | 43 wks | 47 wks | 52 wks | 57 wks |
| Male Treatment | With females | 27.2[a] | 22.9[a] | 23.7[a] | 24.1[a] |
| | Isolated from females | 24.6[a] | 22.4[a] | 23.6[a] | 22.5[a] |
| | Pooled SEM[2] | ±1.86 | ±1.65 | ±1.39 | ±1.98 |
| Breeder Light Source | Sodium Vap. | 21.8[a] | 21.1[a] | 19.3[a] | 23.0[a] |
| | Fluor. | 29.3[a] | 24.4[a] | 26.1[b] | 19.5[a] |
| | Incand. | 26.5[a] | 22.5[a] | 25.2[b] | 26.3[a] |
| | Pooled SEM[2] | ±2.28 | ±2.02 | ±1.71 | ±2.46 |
| Experimental Mean | | 25.9 | 22.7 | 23.6 | 23.4 |

[1] Means within age and treatment with different superscripts are significantly different from each other ($P \leq .05$).

[2] Standard error of the mean.

Table 24. Percent live-dead, normal and abnormal sperm in semen of male turkeys 52 and 57 weeks of age by male treatment and breeder light source treatment

| Treatment | | Classes (%) at 52 weeks of age | | | | Classes (%) at 57 weeks of age | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NU[1] | NS[2] | AU[3] | AS[4] | NU | NS | AU | AS |
| Male | With females | 93.3 | 3.4 | 2.6 | 0.8 | 81.2 | 13.7 | 3.2 | 1.9 |
| Treatment | Isolated from females | 91.2 | 4.1 | 3.3 | 1.4 | 74.7 | 16.9 | 4.0 | 4.4 |
| | Pooled SEM[5,6] | ±0.81 | ±0.56 | ±0.52 | ±0.22 | ±3.88 | ±3.69 | ±0.58 | ±0.38 |
| Breeder | Sodium Vap. | 93.4 | 3.1 | 2.6 | 0.9 | 78.0 | 12.6 | 5.3 | 4.1 |
| Light Source | Fluor. | 92.6 | 3.6 | 3.2 | 0.6 | 72.9 | 21.2 | 2.8 | 3.1 |
| | Incand. | 91.0 | 4.4 | 2.9 | 1.7 | 82.3 | 11.9 | 3.0 | 2.8 |
| | Pooled SEM[5,6] | ±0.10 | ±0.69 | ±0.64 | ±0.27 | ±4.77 | ±4.54 | ±0.71 | ±0.46 |
| Experimental Mean | | 92.3 | 3.8 | 2.9 | 1.1 | 77.7 | 15.4 | 3.6 | 3.3 |

[1] Normal unstained.

[2] Normal stained.

[3] Abnormal unstained.

[4] Abnormal stained.

[5] Standard error of the mean.

[6] No significant differences among treatments.

Table 25. Immune response of male turkeys by male treatment and breeder light source treatment

| Treatment | | Immune response | |
|---|---|---|---|
| | | H/L ratio | Antibody titer[1] |
| Male | With females | 1.0 | 6.1 |
| Treatment | Isolated from females | 1.0 | 6.6 |
| | Pooled SEM[2,3] | ±0.15 | ±0.61 |
| Breeder | Sodium Vap. | 1.1 | 5.3 |
| Light Source | Fluor. | 1.1 | 6.4 |
| | Incand. | 0.9 | 7.3 |
| | Pooled SEM[2,3] | ±0.18 | ±0.75 |
| Experimental Mean | | 1.0 | 6.4 |

[1] Values represent the $\log_2$ of the reciprocal of the last serial dilution at which hemagglutination occurred.

[2] Standard error of the mean.

[3] No significant differences among treatments.

# DISCUSSION

## Light Sources and Growth

In the present study, turkey hens obtained heavier body weights under SV lights than under either FL or IN lights. This response may relate to the slight spectral distribution differences among the various light sources used. The spectral distribution of the SV lights used in this study is concentrated in the 560 to 620 nm range, i.e., yellow and orange light, while that of the FL lights closely simulate that of natural daylight, whose primary spectral ranges between 380 and 700 nm (purple to red), and the spectrum emitted from IN lights is concentrated in the 570 to 700 nm range (yellow to red light). In all cases, each light source contained all components of the visible spectrum, the only difference being the relative proportion of each wavelength represented. It would therefore be unlikely that the differences observed could be attributed strictly to the subtle differences in the spectra of the light sources. Even commercially available colored lights do not effectively screen out other parts of the visual spectrum, possibly explaining why earlier studies by Smith and Phillips (1959) and Kondra (1961) did not find any differences in growth when using colored lights. On the other hand, studies using filtered lights consistently showed better growth response to shorter wavelengths during the earlier stages of development and to the longer wavelengths during later periods of growth (Gill and Leighton, 1984; Levenick and Leighton, 1988). Based on the above statements, there appear to be no logical reasons for the observed differential growth responses in males and females due to the light sources utilized in this

study. From the viewpoint of the turkey grower, the ages at which these differences were noted have no significant economic implication, for turkeys are marketed prior to reaching these ages. Feed efficiency for both males and females was not affected by light source treatment at any time during the growing period. This supports the findings of Levenick and Leighton (1988).

Breeder Phase-Females

In the present study, mean body weight decreased from 10.81 to 9.48 kg under SV light, from 10.79 to 9.45 under FL light, and from 10.99 to 9.69 kg under IN light. These findings are in accord with previous research (Wolford *et al.*, 1963; Thomason *et al.*, 1976; Robel, 1984; and Siopes, 1984a,b).

Results of the present study showed that subsequent egg production was unaffected by adolescent light source. During the breeder period, there was a significant interaction between light source and the presence of the male. In natural mating conditions or with a male in the adjacent pen, hens under SV and FL lights laid more eggs than their counterparts under IN light. When isolated from males, hens housed under FL lights laid the most eggs, with the SV showing the lowest production. Nevertheless, egg production was consistently higher for hens kept under FL lights. Because the SV and FL light treatments closely paralleled each other throughout the egg production cycle (Figure 1), each light may have specific spectral characteristics that enhance egg production more so than IN lights. It has been stated that breeder turkeys are most sensitive to light of the longer visible wavelengths (Scott and Payne,

1937). The SV lights used in this experiment have their highest spectral peaks in the yellow light band (approximately 580 nm), while the FL lights have their highest spectral peaks in the green to yellow band (495 to 590 nm), and IN lamps have their spectral output concentrated in the yellow to red region (570 to 700 nm). The slight differences in spectral characteristics of the various light sources may be sufficient to alter the neurovascular transmission of stimuli from the hypothalamus to the anterior pituitary via the hypophyseal portal vessels which could contribute to the observed differences in egg production.

The results obtained in the present study agree with those of Siopes (1984b) who observed no differences in production between full-spectrum FL or IN light sources. In contrast, Siopes (1984a) found that cool-white FL lights, which have a spectral output concentrated in the shorter wavelengths, depressed egg production late in the breeder period, whereas hens under IN light maintained adequate production levels. The FL lights used in this study have spectra very similar to full-spectrum FL lights. This may explain the disparity in egg production patterns as reported by Siopes (1984a), compared to those reported by Siopes (1984b) and the present study.

The presence of males in this study significantly improved hen-day egg production. The greatest number of eggs were produced by hens with a tom present under natural mating conditions. Hens isolated from toms produced the fewest eggs, while hens with a tom visually and vocally present were intermediate in production. The differences noted in hen-day production were not significant on a hen-housed basis ($p=.17$), although

the same production patterns existed in both analyses. This probably relates to the slightly lower differences in egg production compounded by a breeder light source by female treatment interaction. Also, mortality may have been a contributing factor. Although no females died when a male was in an adjacent pen, mortalities of 5 and 4 % were recorded for females with a male in the pen and females isolated from males, respectively.

The influence of the presence of the male on egg production is in accord with those reported by Bacon and Nestor (1977), who noted that hens in pens adjacent to toms exhibited a higher rate of lay and had longer clutch lengths than hens isolated from males, and Jones and Leighton (1987) observed significant increases in egg production due to the presence of males. Their results showed highest production in pens in which a male was allowed to mate naturally followed by pens in which a male was enclosed in a wire cage in the same pen. Pens in which females were completely isolated from males showed the lowest level of production. Bacon and Nestor (1977) also noted that the incidence of broodiness was lower in pens where males were caged in female pens. Jones and Leighton (1987) reported that the physical presence of males in pens may have been instrumental in decreasing broodiness in those pens as compared to pens of females isolated from males. These authors speculate that the low incidence of broodiness experienced in the presence of males may result from a suppression of prolactin release, an increase which normally accompanies the onset of broodiness in turkeys (El Halawani *et al.*, 1984).

Fertility and hatchability data in this study were unaffected by the light source treatments used in this study. These results support those of Siopes (1984a,b), who noted no differences in fertility or hatchability in hens housed under IN lights as opposed to cool-white or full-spectrum FL lights, respectively. Fertility and hatchability were also unaffected by the presence of males in this study. This finding supports the earlier work of Bacon and Nestor (1977) and Jones (1983).

The results of the present study showed no differences in days to first egg due to adolescent or breeder light source, or due to the presence or absence of a male. All treatment groups laid eggs at either 16 or 17 days after photostimulation. Nestor and Brown (1972) reported that hens exposed to stimulatory light laid their first egg approximately 21 days later. Siopes (1984a) showed that hens under IN and cool-white FL lights produced their first eggs at 19 and 21 days, respectively, following stimulatory lighting. Using full-spectrum FL and IN lights, Siopes (1984b) noted no differences in days to first egg, with both treatments averaging about 19 days.

Egg specific gravity has been used as an indirect measure of egg shell quality. In chickens, Wolford and Tanaka (1970) concluded that egg specific gravity decreases with age, while Nordstrom and Ousterhout (1982) found a negative relationship between egg weight and egg specific gravity, i.e., as weight increases, specific gravity decreases. A similar pattern was seen in this study.

Breeder Phase-Males

Toms in the present study experienced the seasonal decline in semen volume as described by other researchers (Harper and Arscott, 1969; Ogasawara and Fuqua, 1972).

Semen volume in this study was not affected by either breeder light source or light intensity. The FL lights used in this study closely simulate the spectral output of full-spectrum FL lights, and Thurston *et al.* (1982) reported no difference in semen volume when using full-spectrum FL light (173 lux) or IN light (10 lux).

Semen concentration is commonly determined from the packed cell volume (PCV) of the total volume of a semen sample. Some research has shown that that this value may decline with age (Harper and Arscott, 1969; Wall and Jones, 1976; Jones *et al.*, 1977; Leighton and Meyer, 1984; and Sexton, 1986). Other studies have shown that PCV remains fairly constant during the breeder season (Siopes, 1983; Cecil, 1986). It has also been reported that PCV is unaffected by either pen or cage confinement (Ansah *et al.*, 1983). No discernible declines in PCV were present in this study.

Siopes (1983) found no differences in PCV between males on continuous 15 h light per day or several intermittent light treatments. With regard to light intensity, Jones *et al.* (1977) found that toms under increasing natural daylight (2700 lux) or 14L:10D (43.0 and 5.3) produced similar concentrations of semen. On the other hand, Cecil (1986) found that while high intensity (100 lux) versus low intensity (6.5 lux) light had no effect in normal weight males, high intensity light yielded

significantly higher PCV values in low weight males. No differences due to light intensity (21.6 *versus* 86.1 lux) were found in the present study.

In chickens, Sochkan and Bulgia (1981) noted that isolated males had lower quality semen than cocks in the presence of sexually active females. In support of this finding, toms in this study showed slightly higher PCV when in the presence of females, although these differences were not significant. On the other hand, Jones and Leighton (1987) noted that males in the presence of females had lower PCV than isolated males.

In the present study, the percentage of normal sperm was significantly lower and the percentage of abnormal stained sperm significantly higher for toms exposed to FL light only at 57 weeks of age. Although several studies have examined the influence of light intensity on semen quality and quantity (Jones *et al.*, 1977; Cecil, 1986), these investigators did not report the incidence of viable and non-viable sperm. Toms in the present study showed a significantly lower percentage of normal but dead sperm at 52 weeks of age under 86.1 lux of light intensity. The reason for this difference is not apparent.

Although no significant differences were noted in the present study, toms housed with females showed numerically greater percentages of viable sperm at both 52 and 57 weeks of age. In chickens, Sochkan and Bulgia (1981) noted that males kept in sight of females had higher quality semen than isolated cocks. Research by Jones and Leighton (1987) supported these findings using turkeys.

To date, this author knows of no published research that has been conducted to evaluate either H/L ratios or antibody response in turkeys.

Leighton and Gross (personal communication) state that H/L ratios in turkeys are normally much higher than those reported for chickens, and that antibody titers are similar for both species. For both males and females in the present study, both H/L ratio and antibody titer were unaffected by any of the experimental treatments.

## SUMMARY AND CONCLUSIONS

This study evaluated the effects of three light sources (sodium vapor, daylight fluorescent, and incandescent) on growth and reproduction in turkeys, and the influence of the opposite sex on reproduction when using these three light sources. The influence of the various treatments as potential stressors was also evaluated. Male and female Large White turkeys were reared in single-sex pens under one of the three light sources from 8 to 22 weeks of age. At 22 weeks, both males and females were restricted to 6 hours of light per day at an intensity of 21.6 lux. At 33 weeks of age, males were exposed to 16 hours of light per day under the same light sources under which they were reared at intensities of either 21.6 or 86.1 lux. At 35 weeks of age, females were reassigned to the various light sources to achieve all possible combinations of adolescent and breeder light source. Within this design, females were housed in either (a) pens with a male physically present, (b) pens with a male visually and vocally present, or (c) pens completely isolated from males.

Feed efficiency of males and females during the rearing period was unaffected by the light sources used in this study. Body weight of males and females were also unaffected through 22 and 14 weeks of age, respectively.

In the breeder phase of the experiment, neither adolescent nor breeder light source treatment had a significant effect on body weight, hen-housed and hen-day egg production, fertility, hatchability, days to first egg, egg weight, egg specific gravity, or immune response of

females. Semen volume, semen concentration as determined by packed cell volume, semen quality, and immune response of males were unaffected by breeder light source.

The presence of males had no effect on body weight, fertility, hatchability, days to first egg, egg weight, or egg specific gravity. Hen-day egg production was significantly higher for females with a male physically in the pen, followed by females with males visually and vocally present in adjacent pens, and hens isolated from males. In contrast, hen-housed egg production was unaffected by the presence of the males. Immune response, semen volume, concentration or quality of males were unaffected by the presence of females.

These results suggest that since the light sources used in these studies showed no detrimental effect on either growth or reproduction, commercial turkey operations would be well-advised to change their current lighting systems to accomodate more energy efficient light sources for use in their growing and breeding programs. The results also suggest that placing males with females during the breeding season may reduce the incidence of broodiness and improve egg production. Further research is required to see if mingling the sexes during the breeder period has a truly beneficial effect on reproductive performance.

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# Appendix

## Analysis of Variance tables where statistical differences were obtained

Appendix Table 1. Analysis of variance for male body weight at 12 weeks of age

| Source of variation | df | Mean square | F | p |
|---|---|---|---|---|
| Adol. light source | 2 | 1.74 | 3.23 | 0.0440 |
| Error | 91 | 0.54 | | |
| Total | 93 | | | |

Appendix Table 2. Analysis of variance for female body weight at 14, 16, 18, 20 and 22 weeks of age

| Age | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|
| 14 wks | Adol. light source | 2 | 0.82 | 6.22 | 0.0023 |
| | Error | 315 | 0.13 | | |
| | Total | 317 | | | |
| 16 wks | Adol. light source | 2 | 1.34 | 7.65 | 0.0006 |
| | Error | 315 | 0.18 | | |
| | Total | 317 | | | |
| 18 wks | Adol. light source | 2 | 1.17 | 5.49 | 0.0045 |
| | Error | 314 | 0.21 | | |
| | Total | 316 | | | |
| 20 wks | Adol. light source | 2 | 1.10 | 3.96 | 0.0201 |
| | Error | 314 | 0.28 | | |
| | Total | 316 | | | |
| 22 wks | Adol. light source | 2 | 1.15 | 3.65 | 0.0271 |
| | Error | 312 | 0.32 | | |
| | Total | 314 | | | |

Appendix Table 3. Analysis of variance for male body weight gain from 10 to 12 weeks of age

| Source of variation | df | Mean square | F | p |
|---|---|---|---|---|
| Adol. light source | 2 | 0.77 | 5.49 | 0.0057 |
| Error | 89 | 0.14 | | |
| Total | 91 | | | |

Appendix Table 4. Analysis of variance of female body weight gains by age

| Age | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|
| 8-10 wks | Adol. light source | 2 | 0.22 | 7.35 | 0.0008 |
| | Error | 319 | 0.03 | | |
| | Total | 321 | | | |
| 10-12 wks | Adol. light source | 2 | 0.42 | 19.35 | 0.0001 |
| | Error | 318 | 0.02 | | |
| | Total | 320 | | | |
| 12-14 wks | Adol. light source | 2 | 0.22 | 9.11 | 0.0001 |
| | Error | 315 | 0.02 | | |
| | Total | 317 | | | |
| 16-18 wks | Adol. light source | 2 | 0.19 | 8.08 | 0.0004 |
| | Error | 314 | 0.02 | | |
| | Total | 316 | | | |

Appendix Table 5. Analysis of variance for female body weight at 47 and 57 weeks of age

| Age | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|
| 47 wks | Adol. light source | 2 | 0.30 | 3.84 | 0.0408 |
| | Brdr. light source | 2 | 0.08 | 1.05 | 0.3695 |
| | Interaction[1] | 4 | 0.04 | 0.49 | 0.7449 |
| | Error | 18 | 0.08 | | |
| | Total | 26 | | | |
| 57 wks | Brdr. light source | 2 | 0.09 | 1.44 | 0.2634 |
| | Female treatment | 2 | 0.34 | 5.32 | 0.0153 |
| | Interaction[2] | 4 | 0.16 | 2.58 | 0.0722 |
| | Error | 18 | 0.06 | | |
| | Total | 26 | | | |

[1] Interaction between adolescent and breeder light source.

[2] Interaction between breeder light source and female treatment.

Appendix Table 6. Analysis of variance for hen-housed egg production by period

| Time period | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|
| 1-10 wks | Brdr. light source | 2 | 63.41 | 8.87 | 0.0021 |
| | Female treatment | 2 | 1.41 | 0.20 | 0.8226 |
| | Interaction[1] | 4 | 19.10 | 2.67 | 0.0656 |
| | Error | 18 | 7.15 | | |
| | Total | 26 | | | |
| 1-10 wks | Adol. light source | 2 | 13.74 | 1.79 | 0.1950 |
| | Brdr. light source | 2 | 42.69 | 5.57 | 0.0131 |
| | Interaction[2] | 4 | 8.85 | 1.15 | 0.3634 |
| | Error | 18 | 7.66 | | |
| | Total | 26 | | | |
| 1-20 wks | Brdr. light source | 2 | 228.15 | 6.12 | 0.0094 |
| | Female treatment | 2 | 73.79 | 1.98 | 0.1673 |
| | Interaction[1] | 4 | 125.70 | 3.37 | 0.0317 |
| | Error | 18 | 37.30 | | |
| | Total | 26 | | | |

[1] Interaction between breeder light source and female treatment.

[2] Interaction between adolescent and breeder light source.

Appendix Table 7. Analysis of variance of hen-day egg production by period

| Time period | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|
| 1-10 wks | Adol. light source | 2 | 6.65 | 1.18 | 0.3314 |
| | Brdr. light source | 2 | 28.45 | 5.03 | 0.0184 |
| | Interaction[1] | 4 | 11.68 | 2.07 | 0.1279 |
| | Error | 18 | 5.66 | | |
| | Total | 26 | | | |
| 1-10 wks | Brdr. light source | 2 | 31.56 | 5.63 | 0.0126 |
| | Female treatment | 2 | 13.11 | 2.34 | 0.1250 |
| | Interaction[2] | 4 | 7.51 | 1.34 | 0.2934 |
| | Error | 18 | 5.60 | | |
| | Total | 26 | | | |
| 1-20 wks | Brdr. light source | 2 | 83.17 | 3.40 | 0.0560 |
| | Female treatment | 2 | 147.83 | 6.04 | 0.0099 |
| | Interaction[2] | 4 | 81.69 | 3.34 | 0.0328 |
| | Error | 18 | 24.49 | | |
| | Total | 26 | | | |

[1] Interaction between adolescent and breeder light source.

[2] Interaction between breeder light source and female treamtent.

Appendix Table 8. Analysis of variance for semen packed cell volume at 52 weeks of age

| Source of variation | df | Mean square | F | p |
|---|---|---|---|---|
| Brdr. light source | 2 | 32.32 | 4.61 | 0.0380 |
| Male treatment | 1 | 0.01 | 0.00 | 0.9722 |
| Interaction[1] | 2 | 4.02 | 0.57 | 0.5810 |
| Error | 10 | 7.01 | | |
| Total | 15 | | | |

[1] Interaction between breeder light source and male treatment.

Appendix Table 9. Analysis of variance of semen quality variables at 52 and 57 weeks of age

| Variable | Age | Source of variation | df | Mean square | F | p |
|---|---|---|---|---|---|---|
| normal stained | 52 wks | Brdr. light source | 2 | 8.14 | 1.54 | 0.2381 |
| | | Light intensity | 1 | 46.34 | 8.76 | 0.0075 |
| | | Interaction[1] | 2 | 2.88 | 0.54 | 0.5882 |
| | | Error | 21 | 5.29 | | |
| | | Total | 26 | | | |
| normal unstained | 57 wks | Brdr. light source | 2 | 129.90 | 3.89 | 0.0395 |
| | | Light intensity | 1 | 68.75 | 2.06 | 0.1686 |
| | | Interaction[1] | 2 | 94.52 | 2.83 | 0.0855 |
| | | Error | 18 | 33.41 | | |
| | | Total | 23 | | | |
| abnormal stained | 57 wks | Brdr. light source | 2 | 61.94 | 4.12 | 0.0335 |
| | | Light intensity | 1 | 43.52 | 2.90 | 0.1059 |
| | | Interaction[1] | 2 | 41.06 | 2.73 | 0.0919 |
| | | Error | 18 | 15.02 | | |
| | | Total | 23 | | | |

[1] Interaction between breeder light source and light intensity.

# VITA

James Vernon Felts, son of Bobby A. and Janet M. Felts, was born September 11, 1965 in Fairfax, Virginia, and soonafter moved to Ivor, Virginia. He attended Southampton High School in Courtland, Virginia, and graduated with honors in June, 1982. Beginning September, 1982, the author attended Virginia Polytechnic Institute and State University, from which he graduated in June, 1986 with a Bachelor of Science degree in Biology. He began work on his Master of Science degree in Poultry Science at the same institution in September, 1986. The author is currently a junior member of the Virginia Poultry Federation.