A STUDY OF THE EFFECT OF ENVIRONMENTAL LIGHTING ON GROWTH, REPRODUCTION AND BEHAVIOR IN TURKEYS (MELEAGRIS GALLOPAVO)

by

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INTRODUCTION

The effects of light on the different avian species have been of interest to numerous workers for many years. Rowan, 1925, reported that daylength appeared to control the reproductive capabilities of male Juncos. Bissonette (1932) and Scott and Payne (1937) showed that the wavelength of light also could effect reproduction. Others such as Garland, et al. (1961) have shown different production levels at varying intensities of light. Three parameters of light; (1) wavelength, (2) photoregimen i.e., natural daylength or artificially controlled light: dark (L:D) cycles, and (3) intensity have been shown to effect the early growth of birds as well as their reproductive cycles. Early work by Scott and Payne in 1937 demonstrated the influence of colored light on reproductive development in turkeys. More recently, the effect of various light intensities on growth and reproduction has been investigated (Garland et al., 1961; Nestor and Brown, 1972). The literature indicates that little has been done with respect to the effect of photoregimens on the growth of turkeys and that the majority of all light environment investigations have utilized the chicken and quail as experimental subjects.

The purpose of this study is to investigate the effects of two of these factors, wavelength of light and photoperiod on the growth and reproductive capabilities of turkeys. The specific objectives are as follows:

1. to ascertain the effect of red (650 nm) vs. blue (450 nm) vs. white light on growth.

2. to study the effect of wavelength of light during the growth period and its subsequent effect on reproductive fitness and mating behavior.

3. to determine the effect of short intermittant light cycles, (2L:2D) vs. diurnal cycles (12L:12D) on growth parameters and their subsequent effect on reproductive fitness and mating behavior.

4. to determine the histological, biochemical and physiological changes which occur when turkeys are subjected to altered light environments.

REVIEW OF LITERATURE

Growth and Wavelength

Blue and green wavelengths have been suggested as stimulating growth in turkeys (Moyer, 1969) and chickens (Kondra, 1961) respectively. Gill (1973) has reported a trend toward increased weight gains for tom turkeys reared under blue light up to 18 weeks of age and Foss et al. (1967) reported heavier male chicks under blue light. However, Foss et al. (1972) found the best growth rates in birds under green light. Green light has been previously reported as being the most growth stimulatory wavelength by Lauber and McGinnis (1965). In contrast, growth studies by Barott and Pringle (1951), Kondra (1961), Cherry and Barwick (1962), Schumaier et al. (1968) and Wells (1971) have shown no differences using broiler or egg production stock under various wavelengths of light. Woodard et al. (1968, 1969) reported that blue and green light depressed 5 week but not 16 week body weight in quail. Likewise, early growth depression (4 weeks of age) has been reported by Tamimie (1967) for chickens under pink incandescent light sources versus conventional white light bulbs. A recent report by Wabeck and Skoglund (1974) has shown a reduced growth rate in broilers to 9 weeks of age under red florescent light, but no significant growth difference among the blue, green, white, or yellow light treatments. However, birds reared under blue or green lights were always numerically heavier than those in the other treatments. Based on the above reports it can be seen that the reported effects of light wavelength are quite variable. Some possible reasons for this could be due to species differences, age of birds when measurements were made,

differences in intensity of the wavelengths studied, and possibly spectral overlap of light sources in earlier studies.

Growth and Photoperiods

Reference to photoperiod in this manuscript relates to the number of hours of light (L) and darkness (D) in one light:dark cycle. Most descriptions of photoperiod refer to a 24 hour time base. For purposes of this report the following terminology will be employed in order to standardize comparisons between the various studies reported in the literature.

a. Diurnal Regimen - any single L:D cycle equaling exactly 24 hours e.g. 12L:12D.

b. Intermittent Regimen - any L:D cycle equaling 12 or less hours which can be repeated 2 or more times within a 24 hour cycle e.g. 2L:2D; 6L:6D; 1L:1D; etc.

c. Continuous Regimen - either 24L:0D or 0L:24D.

Barott and Pringle (1951), Clegg and Sanford (1951), and Shutze et al. (1959) have all reported that either short intermittent or continuous light regimens stimulated growth in chickens better than a diurnal regimen. Beane et al. (1962, 1965) have suggested that continuous light is a superior growth stimulus than intermittent cycles but Shutze (1959) found no difference. McDaniel (1972), Buckland et al. (1973), and Goodman and Gholson (1975) have all reported better response to intermittent cycles. Cain (1973) noted that female chickens were heavier at 8 weeks on any of several intermittent regimens as compared to a nearly continuous regimen of 23L:1D. However, no effect was found among the males. In a report by Quarles and Kling (1974) no differences

were found in body weight at 7 weeks of age due to intermittent, diurnal, or continuous light treatments, but intermittent light did result in superior feed conversions. Improved body weight gains have been noted by Gill (1973) for tom turkeys reared on an intermittent cycle as compared to a diurnal light regimen of equal total hours. Berg (1973) has reported that same effect for turkey hens. Buckland et al. (1974) have shown that not only were short intermittent regimens superior to diurnal cycles, but that certain types (1L:3D) were better than continuous light cycles.

In general it would appear that while shorter intermittent light regimens may be better than continuous light cycles, either regimen was definitely superior to a diurnal cycle. Weaver and Siegel (1968) have suggested that this may be due in part to feeding behavior being spread out more uniformly over the 24 hour periods. However, this did not account for all the gain. Broiler chickens under continuous light, but with diurnal intensity change, gained less than birds on continuous light of a constant intensity.

Growth and Light Intensity

Barott and Pringle (1951) concluded that for chickens 1 ft. candle (10.8 lux) was adequate intensity for feeding and drinking and that growth was reduced at 12 (130 lux) and 24 ft. candles (260 lux). Similarly increased gains for chickens under low intensity have been reported by Cherry and Barwick (1962), Morris (1967a), and Weaver and Siegel (1968). Touchburn et al. (1968, 1970) have reported increased early growth for turkeys under low intensities. However, this had a tendency to reverse as the turkeys matured. Gill (1973) found the same trend for toms with

those under high intensity becoming heavier around 16-18 weeks of age. Since light intensity appears to alter rates of growth, it is a factor which must be considered in light experiments.

Reproduction and Wavelength

The longer wavelengths of light have been shown to be the most sexually stimulating for testes development in wild birds (Bissonette, 1932), chickens (Foss and Arnold, 1969, 1972), turkeys (Nestor and Brown, 1971), blind or intact quail (Oishi and Lauber, 1973) and for female ovarian stimulation in turkeys (Scott and Payne, 1937), and chickens, (Casey et al., 1969; and Harrison et al., 1969). In addition Nestor and Brown (1971) have reported slightly greater semen volumes from turkeys under red light.

In egg production, Lauber and McGinnis (1965) found pullets matured faster and laid larger eggs under yellow light as compared to green, blue, red or white light treatments.

Work by Schaumier et al. (1968) demonstrated the complexity of results that could occur among chickens reared under white, red or green wavelengths and subsequently reassigned, in all possible combinations, to the above colors during the reproductive period. In general, egg production was poorest under green light and best under white light. An exception was for birds receiving the white rearing - red reproductive light combination. Those birds showed the lowest production of any of the light combinations. Egg production appeared to be highest from birds reared under green wavelengths. This would appear to be contrary to expectations unless there was considerable overlapping with the red and

yellow end of the light spectrum.

Wells (1971) reported a trend to lower egg production during the later stages of production for hens reared in red light. On the other hand, Petersen and Eppershade (1971) found red light increased the rate of lay over blue, green, or white light environments, and egg production was higher under blue light than under white or green light.

Harrison et al. (1969) has reported somewhat comparable results in that pullets and cockerals which were reared under s step-down rearing regimen (hours of light dropped from 16 to 9 from 14-20 weeks) matured faster under green or blue light than under white or red wavelengths. Maturity was measured by the number of days to first egg after the hens were removed from rearing light regimen and placed under 16L:8D white lights. Males reared under green or blue light had larger testes than those under red or white light but showed no differences in the stage of spermatogenesis. Hens transferred to white light at 20 weeks showed no difference in egg production. However, hens reared and maintained during the reproductive stage in red or white light laid more eggs than those hens under the green or blue treatments. For quail, red and white brooding produced the largest testes weight and highest egg production when compared to blue or green light (Woodard et al., 1968, 1969). These results were true for birds held under their original brooding light environment and for those put into white light during the reproductive stage. In addition, blue light had a detrimental effect on fertility. Ott (1964) reported almost zero fertility for birds maintained under florescent pink light while fertility was normal under white light.

It appears that longer wavelengths are more stimulating for early

sexual development. However, whether or not these wavelengths aid production or whether different combinations of wavelengths during rearing and production may be beneficial or detrimental remains to be determined. In addition, wavelengths may affect other factors such as mating behavior, fertility and hatchability.

Reproduction and Photoperiod

Rowan (1925) showed that lengthening the light period with artificial light stimulated sexual development in male Juncos in the nonbreeding season. The use of artificial light is a well established practice in modern egg production for chickens, turkey and quail eggs. This procedure has been instrumental in making it possible to obtain year round egg production in these species. Most of the research in reproduction and light regimens has been concerned with diurnal cycles of various combinations. For chickens, it is generally recommended that 14 to 16 hours of light per 24 hours are needed for optimum egg production, although Morris (1967b) proposed that only 10 hours may be required. He stated that this depends on the rearing regimen. He has shown that if the diurnal rearing regimen utilized a short light period (8 hours or less) then the production light period must be increased to 14-16 hours. However, if the light during the rearing period was 9-14 hours long, no increase in light period was needed and production would equal the production under the first method described. Turkey hens are managed somewhat differently.

Reports by Leighton and Shoffner (1961 a,b), McCartney et al. (1961), Leighton and Potter (1969), indicated that egg production from turkeys was increased if the hens were raised on 10-12 hours of light to 20-24 weeks, then restricted to 6-8 hours of light until 30-32 weeks. When

hens are then placed under a 14-16 diurnal regimen, production starts in about ten days. Males may be included but do not require a light conditioning regimen. However, males must be put on the 14-16 hour stimulatory regimen 2 weeks before the females to ensure adequate semen production.

There is limited information on the effect of non-diurnal regimens on reproduction. Shutze et al. (1961) have shown that a continuous light regimen during the rearing period lowers subsequent egg production in chickens. However, for turkeys, Shoffner et al. (1962) only reported lower egg production when 24 hour lights were used during the entire rearing and reproductive periods. Wilson and Abplanalp (1956) and Bell and Moreng (1973) both reported no significant differences in egg production for hens which received 1-15 minutes of light every 4 hours, compared to the normal pattern of 14 to 17 hours of continuous light per 24 hours. Van Tienhoven and Ostrander (1973) reported a trend to slightly better egg production for chickens on an 8L:10D:2L:4D regimen than those on a conventional 14L:10D regimen.

Tanaka et al. (1965) showed that short intermittent regimens of from 3L:3D to 6L:6D were as effective in stimulating testes growth in male Japanese quail as diurnal regimen of 14 or more hours of light. Both of the above were much more stimulatory than any of the diurnal regimens using 12 hours of light or less. Sexual development in the female Japanese quail appears to respond in the same manner. Bacon (1972) reported on an experiment with quail on intermittent light regimens. The quail received periods of intermittent light ranging from 5 to 17 hours duration followed by continuous darkness for the remainder of the

24 hour cycle. The intermittent schedules were 1L to 1D, 2D or 3D given 3, 4, 5 or 6 times within the intermittent period. Intermittent periods which consisted of five or more 1L:2D, or four or more 1L:3D cycles stimulated sexual maturity for males and females equivalent to the 14L:10D controls.

Work by Brown et al. (1972) with turkeys reported that a 1L;2D schedule repeated 5X daily gave the same egg production as the 14L:10D control schedule. However, they confounded the experiment by leaving the hens exposed to a 5.38 to 10.76 lux light source during the "so-called" 5 dark periods. Light intensity during the light periods was maintained at 53.8 lux. Experiments at this university have shown no significant differences in egg production between turkeys subjected to 5 versus 86 lux when females are maintained on a 16L:8D light regimen (Thomason, 1972).

A number of workers studying wild birds have employed what they called "Skeleton light regimens". These consist usually of one fairly long light period (usually 6 hours) followed by "X" hours of darkness, a short burst of light (usually anywhere from 1 to 60 minutes) and then darkness for the remainder of the light cycle. Hamner (1964) has worked with cycles ranging from 24 to 72 hours duration while others such as Murton et al. (1970) and Shellswell et al. (1975) have limited their work to the 24 hour cycle. Hamner (1964) discovered that maximum testes weight could be stimulated by short light bursts that followed 12 or 36 hours after the start of the longer light period (6L:6D:1L:11D) or (6L:30D:1L:35D). Similarly, Shellswell et al. (1975) reported maximum stimulation of budgerigars for egg production on a 6L:6D:2L:10D regimen. Murton et al. (1969) reported maximum LH levels and Leydig cell activity for birds

stimulated on 6L:0.5D:1L:16.5D but reported maximum spermatogenesis (taken as indicating FSH secretion) for birds receiving the short second light period from 12-18 hours after the start of the first light period. From the work of Hamner and their own work, Murton et al. (1970) have concluded that the wild bird (finches) is light sensitive at two distinct periods of its circadian rhythms. The first period has been defined as needing a light stimulus around 6-7 hours after dawn (i.e. dawn being the start of the major or longest light period in a skeleton regimen) and is thought to stimulate LH secretion. The second period has been described as occuring between 9.5-18 hours after dawn and stimulates FSH secretions (See Loft et al. 1970). As can be seen, work has just begun on the effects of intermittent schedules. More information is needed as intermittent light regimens could be a significant cost saving management practice as the energy problem becomes more critical.

Reproduction and Light Intensity

Morris (1967a) reports that above 5 lux there is no difference in production levels for chickens and that rearing intensity has little effect on subsequent rate of egg production. Parker (1972) and Hughes (1973) have indicated a trend to lower fertility and testes weight under low intensities (3.8 lux or less) but results depended somewhat on the strains of chickens tested. Asmundson (1946) determined that 22 lux was the intensity threshold for turkey egg production. Garland et al. (1961) reported greater turkey egg production at 129 lux than at 5.4 lux. A definite genetic interaction between strain and light intensity was shown by Neston and Brown (1972). They showed that egg production was unaffected by intensity variations in high producing medium white turkeys, but that

production in large whites was light intensity dependent. Thomason et al. (1972) showed no difference due to light intensity (5 lux vs. 86 lux) for a large white strain of turkeys. It would appear that conclusions on the effect of light intensity on reproduction may be governed by the particular strain tested and the light regimen utilized.

Light and Behavior

Various lighting arrangements have been suggested as a means of modifying avian behavior and as management practices for domestic birds. Reduction in cannibalism has been a favorite area and Schumaier et al. (1968) have shown red light to be effective for chickens. Lauber and McGinnis (1965), Wells (1970) and Peterson and Eppenshade (1971) have all observed that chickens under red or blue lights were much less excitable than those under white light environments. The use of blue lighting in chicken houses during catching operations has been recommended by Tuttle et al. (1973). Gill (1972) reported that turkeys raised in blue light were much calmer and easier to work with than those in red or white light. A similar tranquilizing effect has been noted in turkeys under low intensity lighting (Touchburn and Bacon, 1968).

Although several reports were noted earlier on the relationship of colored lights to reproduction in chickens, no reported effects of colored light environments on the mating behavior of domestic species were found. With regards to intensity of lighting, Touchburn and Bacon (1968) reported less lighting in low intensity and Payne and McDaniel (1958) noted less strutting for tom turkeys, suggesting lower sexual stimulation.

Mating Behavior in Turkeys

A brief description of the mating behavior in turkeys is included as this forms one of the areas of interest in this study. For a detailed account see Smyth and Leighton (1953), Schein and Hale (1965) and Carte and Leighton (1969).

Turkeys follow a fairly standard, step by step mating pattern requiring full cooperation between the male and the female. When a male and female turkey are placed in the same pen, the male normally begins a sexual display which is called strutting. Strutting consists of a general erection of all body feathers, fanning of the tail, extending of the wings out and down until they drag on the ground, and the pulling of the head back close to the body. The head may change color taking on brighter red and blue tones. The snood elongates, falling over the beak. The tom emits a low toned pumping noise as it slowly approaches a female. When a female is willing to mate, she assumes a sexual crouch. This consists of the hen crouched with the breast on the ground, head up and fairly close to the body, and the wings slightly extended. The tom mounts the "willing" hen. Her head becomes extended down and forward. The tom orients toward the head and begins to tread up and down on the female. At this stage the mating is classified as an attempted mating. This is followed by a grasping of the base of the wings of the female causing her to raise her tail and evert her vagina. The male lowers his tail around the female's and attempts the copulation. At the time of successful contact of the everted vagina and penile papilla, a momentary freeze is noticed for both male and female. The male then steps down slowly and the female stands, fluffs her feathers and shakes her body. The hen will then often

run, clucking sharply and is not usually willing to mate again for some time. This is termed a "completed mating". If, after the hen has raised her tail and everted her vagina, copulation fails, the hen usually becomes restless and jumps out from under the male. This is called an "incompleted mating" and usually terminates the female's willingness to mate. Schein and Hale (1965) provided an excellent description on the intraspecific stimuli which elicit the male and female behavior while Carte and Leighton (1969) and Leighton and Massincupp (1973) have studied the effects of male rotation, body size, parameters and strain differences on mating ability and fertility. There is, however, to the author's knowledge, no available data on the influence of light wavelength on mating behavior.

MATERIALS AND METHODS

A series of experiments, initiated in February of 1973, were conducted to study how photoperiod and wavelength (color) of light influence growth, reproduction, mating behavior and selected physiological parameters in domestic turkeys. These studies were repeated at different seasons of the year. Two experiments were conducted during the growth phase from day one to 24 weeks of age and two during the reproductive phase.

Growth Phase

Management Procedures

This phase consisted of two trials utilizing a commercial Large White (LW) strain of turkeys and a Medium White (MW) egg production strain maintained at this station. The first experiment was conducted during the spring and summer and commenced on February 13, 1973. The second experiment was conducted during the fall and winter and commenced on August 23, 1973. Approximately 600 LW and 350 MW poults of each sex were utilized in each experiment. Except where stated all management and experimental procedures were the same in Experiments 1 and 2.

Standard management procedures, as practiced at the University's Turkey Research Center, were utilized during the first four weeks in each experiment. During this period the LW poults were assigned by sex to 16 floor pens in the brooder house. Similarly, the MW poults were assigned to 8 additional pens.

Heat in each pen was supplied by a forced air heater-ventilator system via light proof air ducts. Supplemental heat and light were supplied by two infra-red bulbs suspended in the center of each pen. At three

weeks of age, these bulbs were replaced by a single 100-watt incandescent bulb. All poults were maintained on 24 hours of continuous light from day of hatch until four weeks of age.

Commercially prepared rations formulated according to Virginia Polytechnic Institute and State University (VPI&SU) specifications were fed from day of hatch to twenty-four weeks of age (See Appendix A-1, 2, 3)

All poults were wing banded at four weeks of age by sex and randomly assigned to light treatments as outlined in the experimental design in Table 1. Duplicate pens were run for each treatment within each sex. In the first trial, each pen started with 48 LW poults and 23 MW poults. For the second trial, 40 LW and 25 MW poults were placed in all pens.

The light source was provided by a "light box" in the center of each pen. The design of the box (Appendix-B) and proposed intensities (Table 2) of these light sources were based on those given by Gill (1973). Carolina Biological Supply (CBS) filters used to provide narrow bands of red and blue light (CBS - red 650 nm and CBS - blue 450 nm monochromatic filters). The intensity of the light sources as calculated by Gill (1973) based on the transmission specifications of Poff and Norris (1967) were checked by direct measurement. This was done by using both a radiometer (United Detector-21A-power meter) and a standard photographic foot-candle meter (Gossen Light Meter). The measurements from the radiometer were obtained in microwatts/cm^2 (radiometric units) and converted to lux (photometric units).[1/]

[1/] Radiometric units are a physical measure of the absolute physical energy (intensity) of light. Photometric units are a psycho-physical measurement based on the intensity of the light source and on the fact that the eye percieves different wavelengths with different efficiencies.

Table 1 Experimental Design - Growth Phase [1/]

Sex [2/]	Line	Light Environment					
		Intermittent (2L:2D)			Diurnal (12L:12D)		
		White	Red	Blue	White	Red	Blue
M	LW						
	MW						
F	LW						
	MW						

1/ Duplicate pens per treatment per sex.

2/ Male and female data were statistically analysed separately in all Experiments.

Table 2 Specifications of the lamp size, filter characteristics, proposed and measured intensities of the light sources.

Color	Filter	Lamp Size	Proposed Intensity at Head Height[1] (1.83m from the lamp base)	Intensity Measured by a Photo Meter (Lux) Max.[1] (1.83m)	Min.[1] (2.13m)	Intensity Measured by a Radiometer (at 2.13m μW/cm)[2] μW/cm^2[2]	Lux
White	---	60W. 120V. Frosted	86.0 Lux	86.6	58.1	50.0	N.A.[3]
Red	C.B.S. Peak 650 nm. Range 600-700 nm.	300W. 120V. Frosted	86.0	139.9	96.8	124.5	90.8
Blue	C.B.S. Peak 450 nm. Range 400-517 nm.	500W. 120V. Frosted	86.0	10.8	8.1	38.5	10.0

1/ Bird standing head erect directly under the light box. Distance from lamp base varied from approximately 1.83 to 2.13 m depending on age of bird and due to the slight difference between pens in the brooder, grower and breeder houses.

2/ Due to physical limitations of measuring set up, measurement could not be made at 1.83 m.

3/ N.A. - $\mu W/cm^2$ cannot be converted to lux for white light unless the entire energy spectrum of bulb is known. Conversion of the red and white light are based on an idealized conversion of a monochromatic source at 650 (red) and 450 (blue) nanometers. This method works reasonably well for narrow band filters such as the Carolina Biological Supply filters.

The readings from the Gossen light meter were converted from foot-candles to lux (1 fc. = 10.77 lux). The measurements are presented in Table 2.

Specially constructed light-proof pens (see Gill, 1973) were used so that neither daylight nor light from adjacent pens was detectable. Each of these pens was ventilated by air drawn in and out through a light proof air duct system which evacuated air via a time-clock operated exhaust fan. During the first few weeks additional fresh air was brought in via the light proof heater-ventilator system. This system was used to control the pen temperature until the poults produced sufficient body heat to maintain the desired room temperature.

Strict light discipline was maintained at all times. Special red and blue flashlights were used in the colored pens during weighing and routine maintenance procedures. All hallway lights were extinguished and exterior doors were closed whenever it was necessary to enter pens. No one was allowed to enter any pen during a lights-off period.

During both experiments the males, and in Experiment 1 the females, were moved from the brooder house pens to pens in the grower house set under identical light colors and regimens. These pens were also light proof. Ventilation was achieved via a time-clock controlled light proof air duct system. In Experiment 2, the females were reassigned pens within the brooder house to consolidate all light experiments within one-half of the brooder house. Exposure to daylight was minimized by handling the turkeys in black-out hallways and by covering the crates with black plastic during the short period travelling between buildings.

Floor, waterer and feeder space allowances per bird for both experi-

ments are given in Table 3 for the females and Table 4 for males. Fewer poults per pen were started in Experiment 2 than Experiment 1 as it was necessary in Experiment 2 to maintain the poults longer in the smaller brooder house pens. It was known the larger grower house pens would not become available as soon in Experiment 2 as in Experiment 1. This created slightly smaller initial floor, waterer, and feeder spaces in Experiment 1 as identical brooder pens were used in both experiments. The males were moved to the grower house pens at 13 weeks in Experiment 1 and at 17 weeks in Experiment 2 while the females were moved at 16 and 17 weeks of age in Experiment 1 and 2 respectively. At 14 weeks of age any mis-sexed birds were reassigned to pens of the appropriate sex under the identical light treatments to which they were previously exposed.

Feed and water were available ad libitum. The waterer was placed directly under the light box in all pens to ensure that each bird received maximum light stimulation several times a day. Feeders were placed at approximately the same distance from the light box in each pen.

All poults were group weighed at four weeks of age. Bi-weekly body weights were obtained thereafter on an individual bird basis from six to twenty-four weeks of age. Mortality records were maintained and, if it could be determined, the cause of death (i.e. perosis, picking, etc.) was recorded. Feed consumption records were maintained for each bi-weekly body-weight period.

Market quality was determined at 20 weeks for the females and 24 weeks for the males. Each bird was assigned a grade, according to U.S.D.A. specifications (Gulich and Fitzgerald, 1965) and a feather score (Table 5).

The general behavior of the turkeys was observed throughout the

Table 3 Summary of average number of birds per pen, pen location, and floor, waterer, and feeder space per bird for female turkeys during the growth phase. (Experiments 1 and 2).

Experiment	Age In Weeks	Av. No. Birds	Floor Space Bird (dm^2)	Waterer[1/] Number per pen	Waterer[1/] Space (Linear cm)	Feeder[2/] Number per pen	Feeder[2/] Space (Linear cm)	Location
1	4	77	11.2	1	2.4	1	1.7	Brooder House
	16	50	27.4	½	1.8	2	5.1	Grower House
	24	46	29.8	½	2.0	2	5.5	Grower House
2	4	65	13.3	1	3.8	1	2.0	Brooder House
	17	40	21.6	1	4.6	1	3.2	Brooder House
	24	36	24.0	1	5.1	1	3.5	Brooder House

1/ Waterers were 91.4 cm long, accessible from both sides except for 16 - 24 weeks in Experiment 1.

2/ The feeders were 40.6 cm in diameter (128 cm in circumference) and held 23 kg of feed.

Table 4 Summary of average number of birds per pen, pen location and floor, waterer, and feeder space per bird for male turkeys during the growth phase. (Experiments 1 and 2).

Experiment	Age In Weeks	Av. No. Birds	Floor Space Bird (dm^2)	Waterers 1/		Feeders 2/		Location
				Number per pen	Space (Linear cm)	Number per pen	Space (Linear cm)	
1	4	76	11.4	1	2.4	1	1.7	Brooder House
	13	50	39.3	1	3.7	2	5.5	Grower House
	24	48	40.9	1	3.8	2	5.3	Grower House
2	4	65	13.3	1	2.8	1	2.0	Brooder House
	17	41	47.9	1	4.5	2	6.2	Grower House
	24	36	54.5	1	5.1	2	7.1	Grower House

1/ Waterers were 91.4 cm long, accessible from both sides.

2/ Feeders were 40.6 cm in diamter (128 cm in circumference) and held 23 kg of feed.

Table 5 Feathering characteristics used to determine feather scores*

Feather Score	Feathering Characteristics
1	Fully feathered.
2	Bare wing bows and/or bare neck or back at base of wing.
3	Bare wing bows and bare backs.
4	Largely pevoid of feathers

* After Coleman and Leighton, 1969.

experiments under two types of conditions. The most frequent condition was observing their behavior during periods when the observer was performing a specific task within the pen such as weighing birds. The second type condition was for the observer to spend a twenty-five minute period observing the behavior of the birds within the pens. The observer remained motionless except to make notes on the events. Most of the second type observations occurred when the turkeys were 12 weeks of age in Experiment 1. In Experiment 2, additional observations of this type were made on the poults the same day that they were introduced to the different colored light environments.

Necropsy Procedures

Necropsies were performed at 18 and 24 weeks of age in Experiment 1 and at 19 and 24 weeks of age in Experiment 2. The procedures employed were nearly identical for all necropsies. Males and females were sampled on separate days. Two LW and 2 MW birds of each sex were necropsied from each light color regimen combination. All LW birds to be sacrificed were selected at 8:30 a.m., blood samples drawn and the birds placed in a crate in their home pen until they were killed. At 12:30 p.m., the MW birds were similarly selected, blood samples withdrawn and the birds necropsied in the afternoon.

Each bird was killed by electrocution, bled and necropsied. The pineals, anterior pituitary, and the adrenals were removed from both males and females and weighed on an analytical balance to within 0.1 mg. The testes, ovaries and oviducts were weighed on an electronic scale to within 0.01 g.

Testes were fixed in 10% neutral buffered formalin. After fixation,

a center section of each left testis was processed in a Fisher Tissue-matron. The basic processing schedule as published by the Armed Forces Institute of Pathology (A.F.I.P.) (1960) was modified by substituting 70% for 80% ethanol and toluene for cholorform. The tissue was embedded in paraffin and sectioned at 4-6 microns. Sections were mounted and stained with Hematoxylin and Eosin (A.F.I.P., 1960). The seminiferous tubules were measured with an ocular micrometer at ten locations throughout each testis. Only those tubules appearing round or oblong (resulting from transverse or oblique sectioning) were used. The measurements were made at the narrowest cross-section of each tubule. A qualitative judgement of the stage of development (Tabel 6 - Bartholomew, 1949) was recorded on each of the ten tubules measured. The average tubule diameter and testis stage per bird was determined.

Blood Plasma Androgen Assay

Sampling Method

Heparinized blood samples were drawn from LW and MW males at 8:30 a.m. and 12:30 p.m. respectively. Duplicate hematocrits were obtained for each sample. The blood samples were then centrifuged for 10 minutes at 25,000 rpm and the blood plasma frozen at -20°C until the time of assay. The androgen assay method was based on the competitive protein binding procedures developed by Murphy (1964, 1968) as modified by Schrek et al. (1972) and Mirarchi (1975).

Extraction Procedure

Preliminary tests indicated that several modifications were needed. Emulsification of the turkey plasma in the chloroform extraction medium was a problem for samples (a) extracted in a chloroform volume of less

Table 6 Stages of testicular development*

Stage	Description
1	Resting spermatogonia only.
2	Spermatogonia dividing but only a few spermatocytes present.
3	Many spermatocytes.
4	Spermatocytes with spermatids.
5	Spermatids with a few sperm.
6	Full spermatogenic activity with many sperm.

* After Bartholomew (1949).

than 10X the plasma volume (b) in samples extracted shortly after being thawed. A second discovery was that the longer a sample remained at room temperature, the higher the androgen reading. This became more pronounced for samples left out for a period of two hours or more. Therefore, the time of sampling should be controlled fairly closely. In the thawing to room temperature procedure as outlined by Schreck et al. (1972) or Mirarchi (1975), the time to room temperature could vary with the sample volume and with the room temperature. The final sample temperature could also vary from day to day. In addition, samples heated for 30 to 60 minutes before extraction gave better duplicate readings than those heated for 15 minutes or less. With these considerations in mind the following procedure was used during extraction. The original plasma sample (usually 3-6 ml) was placed in a water bath at 41°C. (body temperature of birds) for 5 minutes. All samples were thawed within this time limit. Duplicate samples of the desired extraction volume were removed with an Eppendorf pipette, placed into a 15x125 mm extraction test tube and replaced into the water (41°C) bath for 30 minutes. The original plasma was immediately returned to the freezer for future reuse. The first time a sample was extracted 0.75 ml of plasma was used per duplicate. About 60% of the samples extracted at this volume fell within the range of the st ndard curve. The rest needed either a larger or a smaller volume of plasma to give an androgen level within the standard curve.

The 15x125 mm test tube was removed from the water bath after 30 minutes and a volume of redistilled chloroform (laboratory grade - Fisher) 10X that of the plasma was added to the test tube. If the plasma volume was 0.3 ml or less, 3 ml of chloroform was added. One drop of 4N NaOH

was added to each tube, which was then vigorously shaken for 60 seconds (Vortex mixer). The chloroform layer (lower) was then drawn off using a disposable Pasteur pipette and placed in a clean 15x85 mm culture tube. The chloroform extract was evaporated to dryness at 40°C under a stream of air filtered through Anhydrous $CaSO_4$. This extraction procedure was repeated and the second extraction was combined with the first by drying it in the same 15x85 mm culture tube as previously used. The samples were covered and refrigerated until assayed. All samples were assayed within 72 hours of extraction.

Competitive Protein Binding Assay

Culture tubes containing dried extracts were removed from refrigeration and allowed to reach room temperature. One ml of sex hormone binding globulin (SHBG) saturated with ^{3}H-testosterone [10 ng 1,2,6,7-H-testosterone (2.275 μCi) in 100 ml of 0.25 percent human late pregnancy (third thimester) plasma in 100 ml deionized water] was added to each tube. Culture tubes were shaken gently for 10 seconds, placed in a 45°C water bath for 5 minutes, and then transferred to an ice bath for 10 minutes. After 5 minutes in the ice bath each tray of tubes was shaken gently for 30 seconds. Eighty mg of florisil (60-100 mesh, Sigma Chemical Co; water washed and dried at 200°C and allowed to cool slowly for 24 hours) were added to the first tube which was shaken gently for 30 seconds and returned to the ice bath. Fifteen seconds following shaking, another tube was processed in the same manner. Intervals between tubes followed this pattern throughout the assay. At the start of shaking the fifth tube a 0.5 ml aliquot of the supernatant was withdrawn from the first tube and placed in a liquid scintillation vial. Intervals between withdrawal of

the supernatant followed the pattern previously described. After all the culture tubes were processed, 10 ml of scintillation fluid (Aquasol, New England Nuclear) were added to each vial and allowed to stand for at least two hours. Vials were then counted on a Beckman LS-100C scintillation counter. All samples were assayed in duplicate.

Standard Curve

Zero, 0.25, 0.50, 1.0, 2.0, 3.0 and 4.0 ng stock solutions of testosterone were prepared in redistilled ethanol for use as standards in the procedure. Pure ethanol served as the control or zero standard. Stock solutions were removed from refrigeration and allowed to stand five minutes before use. Two 0.1 ml aliquots were removed from each standard stock solution and placed in separate 15x85 mm culture tubes. Aliquots were evaporated to dryness at 40°C under a stream of air filtered through anhydrous $CaSO_4$. Standards were assayed counted and adjusted for quenching together with the plasma samples of unknown androgen concentration. The standard curve was prepared by plotting the percentage of ^{3}H-testosterone remaining bound to the sex hormone binding globulin (SHBG) against the known concentrations (ng) of testosterone present. The zero or control standard was considered as having 100 percent ^{3}H-testosterone remaining bound to the sex hormone binding globulin.

Determination of Androgen Concentration

After all samples were assayed, counted and adjusted for quenching, the percentage of ^{3}H-testosterone remaining bound to the SHBG (percent bound) was calculated. The level of plasma androgen (ng) was determined from the standard curve. Inevitably, values for a few samples fell either entirely off or onto the flattened portion of the standard curve. These

samples were assayed again at a later time using an appropriate volume of plasma. This resulted in a change in the percentage of ^{3}H-testosterone remaining bound to the SHBG and caused movement of the value for the sample to a more precise (greater slope) portion of the curve. In addition, duplicate samples in which the percent bound values varied by greater than 10% were reassayed. In the event that a plasma sample was assayed two or more times a mean value was calculated and used as the androgen concentration. Androgen concentrations (ng) from the standard curve were multiplied by the appropriate numerical factor to yield a reading in ng/ml.

Accuracy, Precision and Percent Recovery

The exact procedure followed in preparing culture tubes for tests of accuracy and precision is described in Appendix C. Tubes containing known concentrations of testosterone were subjected to both the extraction and assay procedures each time unknown samples were analysed. Androgen levels were then calculated in the manner previously described. Precision and accuracy, expressed as the coefficient of variation and the mean, respectively, for the androgen assay are given in Table 7.

The assay procedure performed to the author's satisfaction at all androgen concentrations tested.

Procedures followed to determine percent recovery for the extraction of androgen are described in the Appendix (C-2). Tritiated testosterone having a known number of counts per minute was added to each culture tube and evaporated to dryness. The volume of plasma to be tested was added to all but five of these "hot" tubes and all tubes were run through the extraction procedure described. The chloroform extracts were

Table 7 Precision and accuracy of the androgen assay.

Actual ng. Testosterone Per Sample	Number of Samples	ng. of Testosterone[1] recorded $\bar{x} \pm$ S.D	Coefficient of Variation (%) [2]
0.4	24	0.46 ± 0.098	21.5
0.8	30	0.88 ± 0.157	17.9
1.0	26	1.07 ± 0.151	14.9
1.6	19	1.56 ± 0.295	18.9
2.0	20	1.96 ± 0.450	23.0
3.0	19	3.02 ± 0.466	15.5

1/ Mean value indicates accuracy of method, i.e., the closer the recovered mean value is to the actual ng. placed in the sample the greater the accuracy.

2/ This is an indication of precision. The smaller the value the more precise the assay, i.e., you get almost the same value.

evaporated to dryness in scintillation vials, scintillation fluid was added and all vials were counted by the Beckman LS-100C counter. Readings for the scintillation vials were used to calculate percent recovery as follows:

$$\% = \frac{\overline{X}\ \text{CPM}(^{3}\text{H-testosterone})\ \text{from each extraction with plasma}}{\overline{X}\ \text{CPM from five extractions without plasma}} \times 100$$

where CPM = counts per minute.

Percent recovery for the volumes of plasma used in the androgen assay were as seen in Table 8.

Results indicated a trend for percent recovery to decrease as the volume of plasma extracted increased. All values for androgen level were corrected for percentage recovery and original extraction volume to give a final value in nanograms per ml.

Reproductive Phase

The use of a restricted light conditioning period during the growth phase just prior to stimulating egg production has become a recommended practice for Virginia breeder turkey hens. This restriction has generally consisted of allowing only 6-8 hours of light per 24 hours for 8-12 weeks prior to stimulating egg production via a 16L:8D light regimen. Therefore, as this conditioning treatment was a natural part of commercial turkey breeder rearing management, modifications of the conditioning light regimens were incorporated into the growth phase light treatment at 24 weeks of age.

In both Experiment 1 and 2, the LW line was removed from all light treatments and the MW egg production line was retained for the reproductive studies. All birds were maintained under their original light

Table 8 Percent recoveries for the volumes of plasma used in androgen assay.

Volume of Plasma Extracted (ml)[1/]	Number of Samples[2/]	Average % Recovery	Coefficient of Variation
0.10	10	90.8	2.7
0.20	10	86.4	3.6
0.40	23	78.2	5.5
0.50	10	75.1	6.3
0.60	9	74.5	3.1
0.75	17	77.0	4.0

1/ Where volumes of plasma greater than 0.75 ml were required to enable detection of androgen on the standard cuve, dual extractions of two of the above volumes were conducted and the extracts combined.

2/ Number of samples refers to number of samples which contained both "hot" testosterone and plasma.

color until placed under a stimulatory 16L:8D regimens. However, the restricted light regimens varied from Experiment 1 to 2.

In Experiment 1, the females which had been on the 2L:2D intermittent regimen were placed on a restricted intermittent 1L:3D regimen. Those females on the 12L:12D diurnal regimen were switched to a 6L:18D restricted diurnal regimen. Therefore, all females were restricted to the recommended 6 hours of total light per 24 hours. The females remained on this regimen until 37 weeks of age. The males were maintained under the same light color and regimen as they had during the growth phase until 35 weeks of age. At 35 weeks of age all males were increased to 15 hours of intermittent or diurnal light to ensure semen production by the start of the mating trial period.

In Experiment 2, the conditioning period regimen started out the same as in Experiment 1, i.e. 1L:3D or 6L:18D, except that the males were also put under the restricted light regimen. The males were restricted in the hope of increased sexual activity and semen production when they were later switched to the sexually stimulatory long light days. However in Experiment 1, the hens under the six hours of intermittent light started to lay between 26-27 weeks of age. By 37 weeks of age more than 75% of the hens from the red and white intermittent condition pens were about to or had started to lay eggs (determined by checking the number hens which would evert their oviduct under abdominal stimulation). As the possibility of clock failure or some other unrecorded stimulatory source could not be entirely ruled out, the 1L:3D regimen was again employed in Experiment 2. However, at the start of 28 weeks of age, with several hens laying in both the red and white intermittent pens, all tom

and hen pens were switched to the 6L:18D regimen. Egg production ceased and no hens were laying at 37 weeks of age. An Ohio station report by Brown et al. (1972) has indicated that certain intermittent regimens will stimulate turkeys to lay.

In a further attempt to increase male mating activity, the males in Experiment 2 were switched to 16 hours of light and their designated reproductive phase light color at 35 weeks of age. Therefore, the males had two weeks to adjust to the reproductive phase light color prior to the initiation of the mating trials.

At 37 weeks of age in both Experiment 1 and 2, the males and females were culled and the remaining birds randomly assigned from within the growth phase environment to the appropriate reproductive light color as indicated by the Experimental Design in Table 9. In Table 9 the Growth Phase refers to the period from 4-37 weeks of age. The Reproductive Phase refers to the time from the start of the Mating Behavior trials at 37 weeks of age until the termination of the study 16 (Experiment 1) or 22 weeks later (Experiment 2). Intermittent regimen refers to those birds that spent all or most of their growth phase under an intermittent regimen (2L:2D followed by 1L:3D) while diurnal refers to those birds that spent the growth phase under a diurnal regimen (12L:12D followed by 6L:18D) as outlined above.

At the start of the reproductive phase all females were saddled for identification and protection during the mating trials. The primary flight feathers on each female wing were clipped to ease in saddle recognition. Black spray paint markings were used to identify each male within a pen.

Table 9 Experimental design - Reproductive Phase.

Growth, Phase, Light Environment[1]		Reproductive Phase Light Environment[2] (16L:8D)		
Regimen	Color	White	Red	Blue
Diurnal[3]	White			
	Red			
	Blue			
Intermittent[3]	White			
	Red			
	Blue			

1/ 4-37 weeks of age, the start of mating trials.

2/ From 37 weeks to termination of the Experiment

3/ Diurnal refers to those birds that spent the growth phase and diurnal regimens of 12L:12D followed by 6L:18D. Intermittent refers to those birds that spent all or most of the growth phase under Intermittent regimens of 2L:2D followed by 1L:3D.

Each of the 18 main pens consisted of an A pen with four males and a B pen with eight females. Males and females were readily visible to each other through the wire door and that part of the partition not occupied by the trap nest. Each tom was provided with 150 dm^2 of floor space, 32 linear cm feeder space and 11.4 linear cm waterer space. Hen allowances were 85.5 dm^2 floor space, 16 linear cm feeder space and 5.7 linear cm of waterer space. Each pen of hens had access to four standard turkey trap nests.

All light sources were the same as employed in the growth phase. Each A and B pen contained one light box which gave intensities at head height as described in Table 2. Each main pen was constructed and ventilated in such a manner that neither daylight nor light from adjacent pens was visible. Time clocks were adjusted to a 16L:8D regimen for all pens. The light treatments were randomly assigned to the reproductive pens and were re-randomized again in Experiment 2.

Following an adjustment period of 2-3 days in their new light environments, mating behavior trials were initiated on November 5, 1973 (Experiment 1) and on May 7, 1974 (Experiment 2). Mating trials were conducted Monday through Friday for five weeks in Experiment 1 and six weeks in Experiment 2. Only three of the four males in each pen were used. The fourth male was maintained as a spare in case of mortality. Each male was placed into the female pen for one 15-minute period per day for the first week and for one ten-minute trial per day the following weeks. In Experiment 2, a sixth week with 15-minute trials was added. The order of appearance of the males in the female pen was rotated daily on a fixed schedule. All females were forced off the trap nests which

were locked shut while the mating trials were in progress.

Daily records were kept for each tom indicating which females were "willing" to mate, those still "willing" at the end of a trial, and the number of "attempted", "completed" or "incompleted" matings per hen. Which males would strut in the female pens and the approximate time spent doing this were also recorded. Any unusual behavior patterns were recorded on the record sheet. Two observers made subjective comparisons between the different colored light pens, especially during the last two weeks of the trials. Seven trained observers were employed at different times throughout the study. Observers A, B and C operated every day with a fourth, and sometimes a fifth, observer being randomly employed from the remaining four (D,E,F and G) depending upon the work schedule at the Research Center. Observers were rotated among pens with no one watching the same two pens two days in a row. After the first week, the activity of most pens was low enough that each observer could easily watch two adjacent pens by moving quietly back and forth from pen to pen. Mating trials took place in the back pen while all observations were made through the wire partition by the observer in the front pen. The bottom half of the observer was screened from view by the trap nests and most of the birds showed little reaction to movements of the observer during mating activity. All trials were conducted between 12:30 and 4:30 p.m. As all pens could not be done simultaneously, the order of observation was rotated daily.

At the end of the mating behavior study, heparinized blood samples (10 ml) were drawn from each of the males used in the mating trials. Hematocrits were taken, the blood samples centrifuged and the plasma

removed. All plasma samples were stored at -20°C until they were analysed for androgen levels by the method described previously.

Egg production and feed records were maintained from day one (the start of the 16L:8D regimen) until the end of the experiment. Experiment 1 was terminated at 16 weeks due to budgetary restrictions while Experiment 2 ran 22 weeks of stimulatory lights, a period comparable to a commercial breeders reproductive program.

Broody control was initiated at the end of the mating trials. During the mating trial broody hens, if any occurred, were not removed in order to maintain an equal number of hens per pen. The method used to detect broody females was to palpate each hen found on the nest in the evening. A female was considered broody if she was on the nest two consecutive evenings without having an egg in the oviduct or having laid during that period. Broody females were placed in a wire floor broody coop under their appropriate color light for five days and then returned to their pen.

Egg production and feed consumption records were maintained from day one through to the end of each experiment. All birds were fed a commercial prepared breeder ration (Appendix A-3). Birds were weighed at day one, every eight weeks and at the end of the experiment.

The volume of semen produced per male per milking was measured seven times in Experiment 1 and twelve times in Experiment 2, starting at week one. Natural mating was the only means of insemination during the mating behavior trials. Artificial insemination was started two weeks after the last week of mating trials in each experiment. Each female was inseminated then a minimum of 0.025 cc of pooled semen from the males in the corresponding A pen. A clean syringe was used for each pen to minimize

any possible disease transfer. In Experiment 1 the hens were inseminated weekly for six weeks and bi-weekly thereafter. Weekly inseminations were used throughout Experiment 2.

Fertility during the natural mating period was determined from the eggs set in the first three hatches in both experiments. Eggs from the artificial insemination period were set at bi-weekly intervals starting with the fourth set two weeks after the first artificial insemination. Fertility records were kept on an individual hen and on a pen basis.

Statistical Analyses

Statistical analysis on data collected during the Growth Phase was conducted on each sex and experiment separately. Body weight gains were analysed using the average pen weight as a three factor factorial analysis (Color x Regimen x Line). As each pen contained both lines the feed efficiency could not be calculated per individual line. Therefore, feed efficiency was analysed as a two factor factorial (Color x Regimen).

The necropsy data was analysed using multivariate analysis of variance techniques (Kramer, 1972) for a 3 way factorial (Color x Regimen x Line). The data from each line for the blood plasma androgen levels during the Growth Phase were analysed separately. This was done as the blood from each line was collected at two different times of the day. Androgen levels have been shown to have cyclic fluctuations in chickens (Schanbacher et al., 1974) as well as in man (Smals et al., 1974) depending on the time of day. Therefore, androgen levels were analysed as a 2 way factorial (Color x Regimen) with duplicate samples per bird.

The data from the mating behavior trials and the Reproductive Phase were analysed separately by experiment due to differences in the conditioning

part of the growth phase. The initial analysis was treated as a 3 way factorial [Growth Phase Color (C1) x Growth Phase Regimen (R) x Reproductive Phase Color (C2)] without replication using the C1 x R x C2 interaction as the error term. When there were no significant 1st order interactions, these interactions were pooled with the 3 way interactions.

All percentage data (except for female sex drive) was subjected to weighted arcsine transformations for unequal numbers of observation as given by Freeman and Tukey (1950). Female sex drive data was analysed using unweighted arcsine transformations.

Analyses of variance were checked for significance at the P= 0.05 and P= 0.01 levels. Where indicated, $P \leq 0.05$ means that the level of significance was between the $P \leq 0.05$ and the P= 0.01 levels . Significance levels indicated $P \leq 0.01$ means that these factors were tested for significance at the P= 0.01 level.

All analyses of variance calculation were performed on the VPI & SU's computer system using the Statistical Analyses System (SAS) programs developed by Barr and Goodnight (1972).

RESULTS

Growth Phase

Growth

The average body weight gains (BWG) for the females are given in Table 10 (Experiment 1) and Table 12 (Experiment 2) for selected growth periods by light-color, light regimen and by lines. Analyses of variance tables are found immediately following (Tables 11 and 13).

The LW females gained significantly more than the MW birds for all growth periods (Tables 11 and 13; Figures 1 through 4). It can be seen from Figures 1 and 2 that hens on the intermittent 2L:2D regimen fairly quickly showed a body weight gain advantage over those reared on the diurnal 12L:12D regimen. The advantage was significant by 10 weeks of age and was maintained through 24 weeks (Tables 11 and 13). However, the main divergence occurred between 4 and 16 weeks. When the body weight gain from 16-24 weeks was compared there was no significant difference between regimens (Tables 11 and 13).

The effect of white, red, or blue light color on weight gains is shown graphically in Figures 3 and 4. By 10 weeks of age, hens reared in blue light showed a significantly greater gain than those reared under white or red light. BWG under blue light declined slowly up to 16 weeks, then quite sharply from 16 weeks on (Figures 3 and 4). At 16 and 18 weeks of age there were no longer significant effects of light color. However by 24 weeks of age hens under both red and white light showed significantly greater gains than those maintained under blue light (Tables 11 and 13). Tables 10 and 12 show that from 16-24 weeks hens under blue light gained on the average 0.5 kg less than those under red and white lights.

Table 10 Female body weight gains (Kg) summarized over various growth periods of light color, light regimen and lines (Experiment 1).

Treatment[1/]	4-10 Weeks (Kg)	4-16 Weeks (Kg)	4-18 Weeks (Kg)	4-24 Weeks (Kg)	16-24 Weeks (Kg)
Color					
White	2.2[a]	4.6[a]	5.0[a]	6.3[a]	1.7[a]
Red	2.3[b]	4.6[a]	5.1[a]	6.5[a]	1.8[a]
Blue	2.4[c]	4.7[a]	4.9[a]	5.9[b]	1.3[b]
Regimen					
2L:2D	2.4[a]	4.8[a]	5.2[a]	6.4[a]	1.6[a]
12L:12D	2.2[b]	4.5[b]	4.8[b]	6.1[b]	1.6[a]
Line					
LW	2.8[a]	5.7[a]	6.1[a]	7.6[a]	1.9[a]
MW	1.8[b]	3.6[b]	3.9[b]	4.8[b]	1.2[b]
Experimental Mean	2.3	4.6	5.0	6.2	1.6

1/ Means within each growth period and treatment subclass designated with different superscripts are significantly different ($P \leq 0.05$).

Table 11 Analyses of variance of female body weight gains by growth periods.(Experiment 1)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$)				
		4-10 Weeks	4-16 Weeks	4-18 Weeks	4-24 Weeks	16-24 Weeks
Color (C)	2	81.4**	7.8	31.3	595.6**	714.5**
Regimen (R)	1	96.3**	700.4**	952.0**	763.3**	1.4
Line (L)	1	6324.3**	25916.7**	29348.8**	46314.8**	2940.0**
C X R	2	7.2	2.0	31.4	51.3	48.7
C X L	2	1.9	16.8	13.9	.6	23.4
R X L	1	5.4	13.1	41.7	109.4	46.8
C X R X L	2	0.4	0.4	0.9	27.4	34.5
Error	12	5.1	31.8	41.9	51.0	40.1
Total	23					

* $P \leq 0.05$.
** $P \leq 0.01$.

Table 12 Female body weight gains (Kg) summarized over various growth periods by light color, light regimen and lines. (Experiment 2)

Treatment[1/]	4-10 Weeks (Kg)	4-16 Weeks (Kg)	4-18 Weeks (Kg)	4-24 Weeks (Kg)	16-24 Weeks (Kg)
Color					
White	2.2[a]	4.6[a]	5.3[a]	7.0[a]	2.4[a]
Red	2.2[a]	4.7[a]	5.3[a]	6.9[a]	2.2[b]
Blue	2.4[b]	4.8[a]	5.4[a]	6.6[b]	1.8[c]
Regimen					
2L:2D	2.3[a]	4.8[a]	5.4[a]	6.9[a]	2.1[a]
12L:12D	2.2[b]	4.6[b]	5.2[b]	6.7[b]	2.1[a]
Line					
LW	2.8[a]	5.7[a]	6.5[a]	8.4[a]	2.6[a]
MW	1.7[b]	3.6[b]	4.1[b]	5.2[b]	1.1[b]
Experimental Means	2.2	4.7	5.3	6.8	2.1

[1/] Means within each growth period and treatment subclass designated with different superscripts are significantly different $P \leq 0.05$).

Table 13 Analyses of variance of female body weight gains by growth phases.(Experiment 2)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$)				
		4-10 Weeks	4-16 Weeks	4-18 Weeks	4-24 Weeks	16-24 Weeks
Color (C)	2	94.6**	66.6	10.5	254.6*	580.7**
Regimen (R)	1	141.1**	246.0**	340.8**	315.1*	4.3
Line (L)	1	6933.8**	26945.2**	34129.4**	58938.0**	6181.4**
C X R	2	3.2	8.8	10.1	21.7	5.7
C X L	2	2.2	4.7	3.8	5.2	17.5
R X L	1	0.0	0.0	0.3	8.4	9.6
C X R X L	2	0.1	4.5	21.2	104.3	68.6*
Error	12	9.6	19.3	27.8	38.4	11.9
Total	23					

* $P \leq 0.05$.
** $P \leq 0.01$.

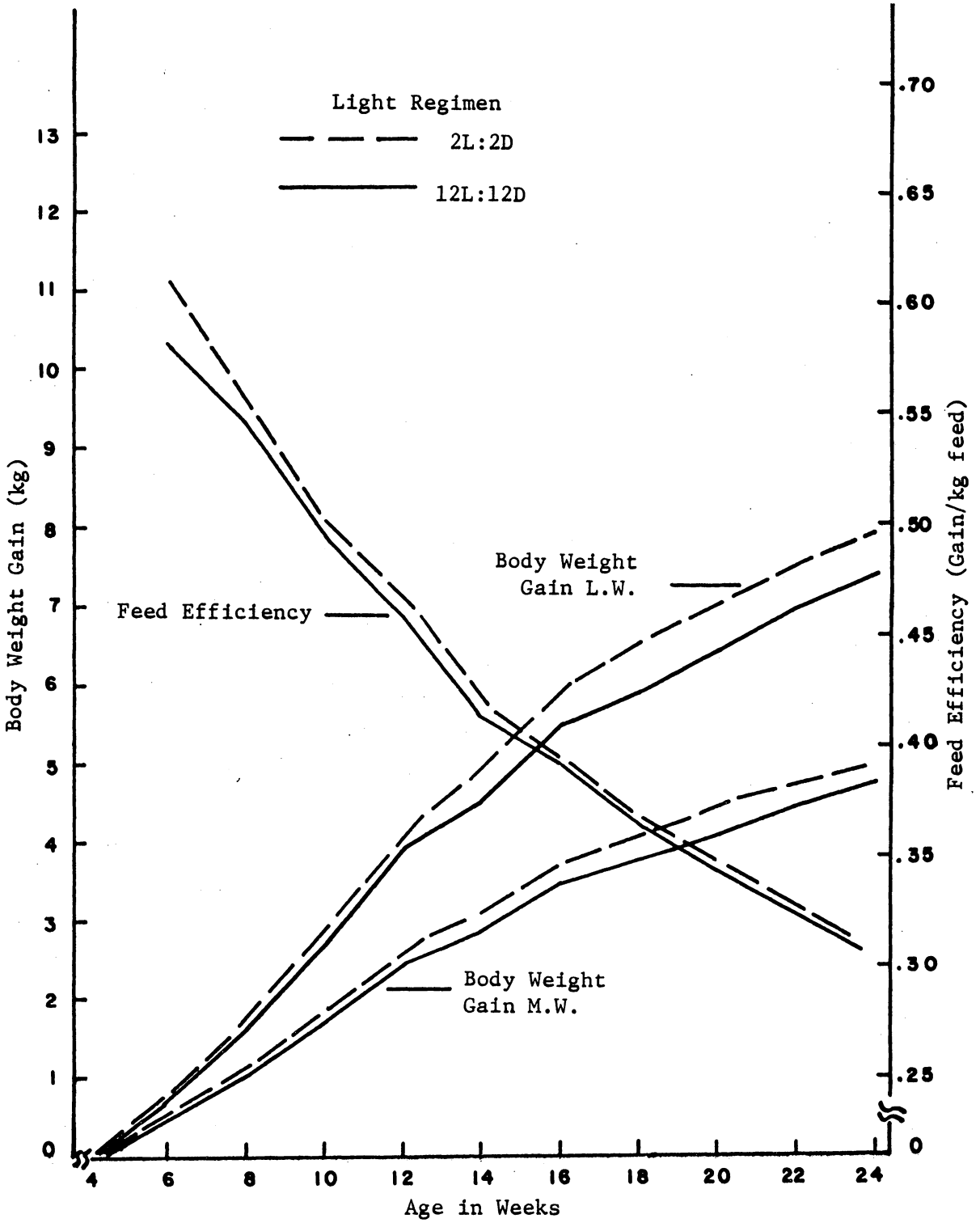

Figure 1. Body weight gain for L.W. and M.W. female lines and cumulative feed efficiency from 4 to 24 weeks of age by light regimen (Experiment 1)

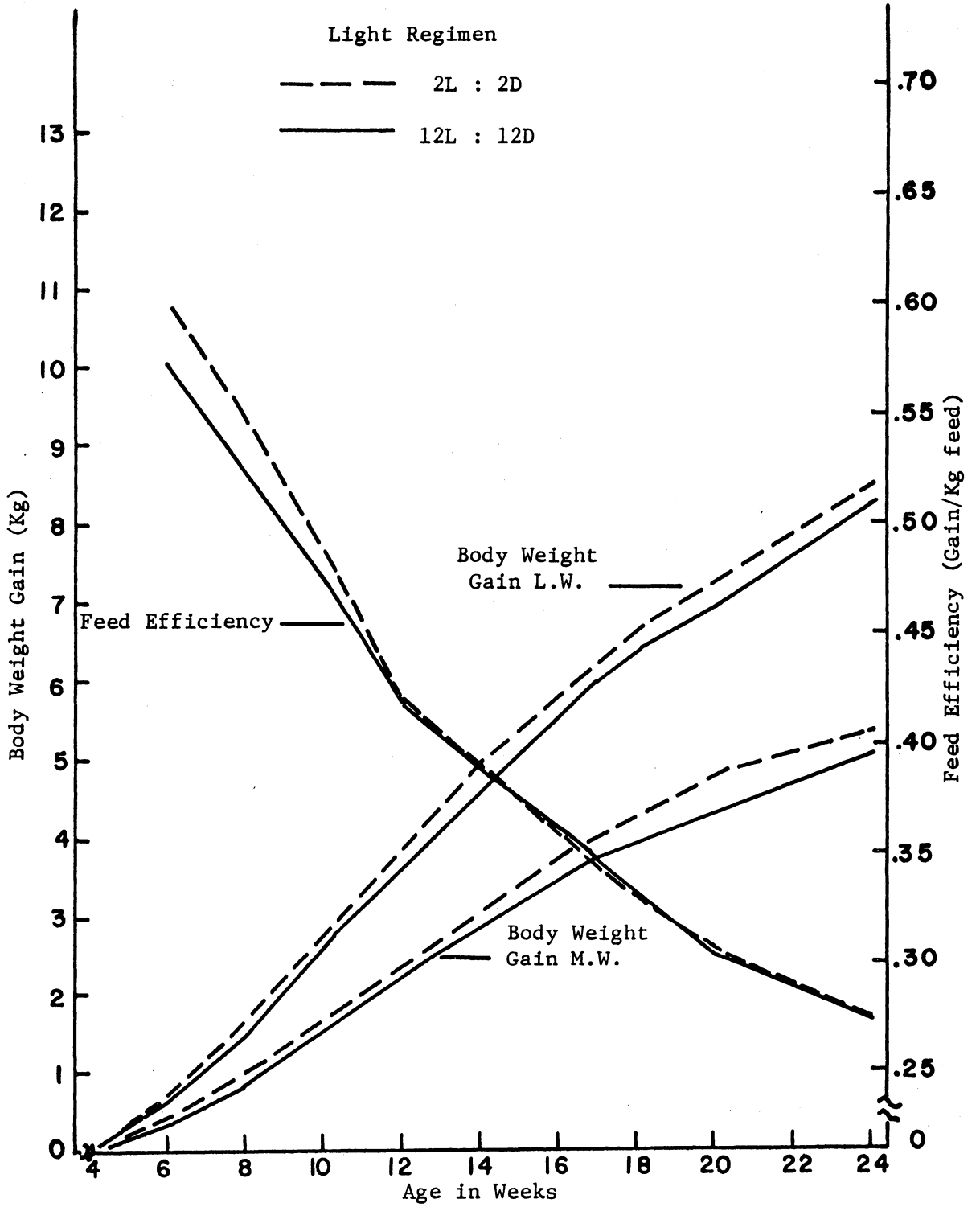

Figure 2. Body weight gain for L.W. and M.W. female lines and cumulative feed efficiency from 4 to 24 weeks of age by light regimen (Experiment 2)

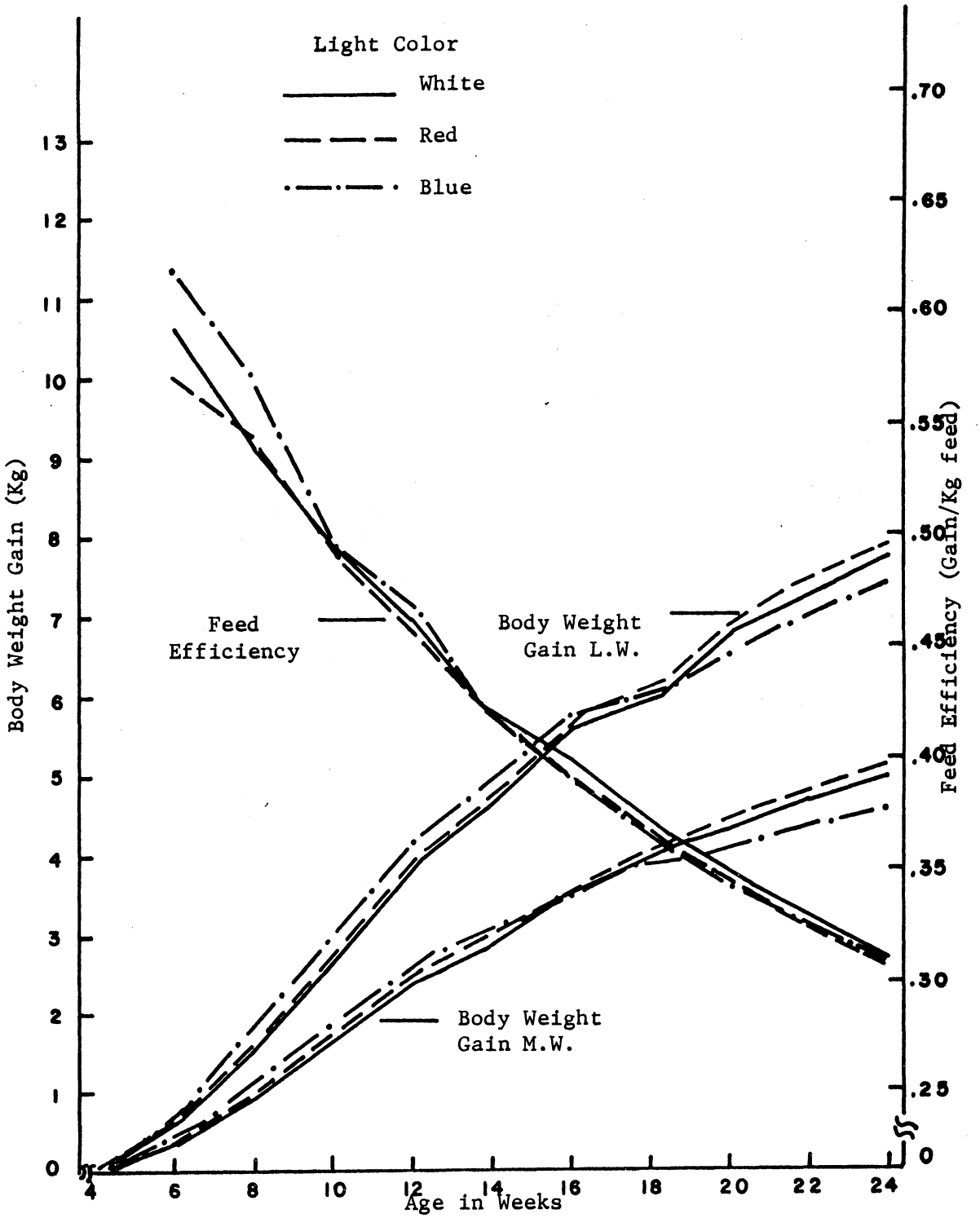

Figure 3. Body weight gain for L.W. and M.W. female lines and cumulative feed efficiency from 4 to 24 weeks of age by light color treatment (Experiment 1)

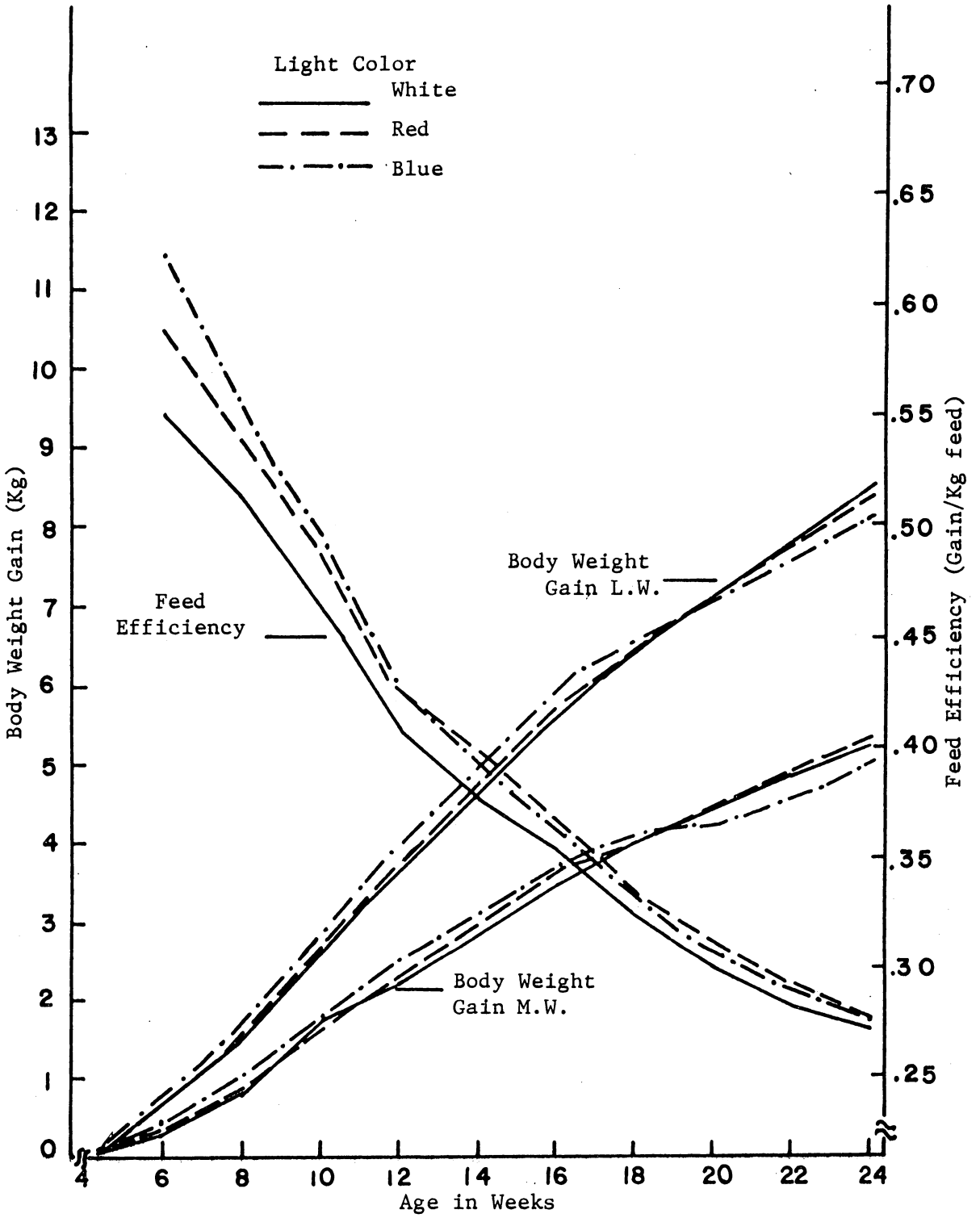

Figure 4. Body weight gain for L.W. and M.W. female lines and cumulative feed efficiency from 4 to 24 weeks of age by light color treatment (Experiment 2)

Average male body weight gains are given on Tables 14 and 16 for Experiments 1 and 2 respectively and illustrated in Figures 5 through 8. Analyses of variance of this data are presented in Tables 15 and 17.

As with the females, the LW males consistantly outgained the MW male line. The early growth stimulatory effect of the 2L:2D regimen was also evident for toms in Experiment 1 (Figure 5) and up to 10 weeks in Experiment 2 (Figure 6). After the 10th week in the second experiment, there were no significant differences in weight gain that could be related to light regimen. However, the MW line did appear to exhibit a response to intermittent light (Figure 6). The LW line appeared to do equally well under either regimen. The interaction of light regimen and line was significant for the 4-24 week period (Table 17).

The biphasic growth response of the hens reared under the blue lights also appeared in the toms. Between 10 and 16 weeks of age the toms reared under blue lights showed a significantly greater BWG than those reared under red or white lights. After 16 weeks the toms under the blue light regimens showed a marked reduction in BWG. This can be readily seen by the sharp drop for the blue BWG line for both LW and MW in Figure 7 and for the MW in Figure 8. The LW line in Experiment 2 seemed to show a more gradual decline in BWG under blue lights than in Experiment 1. Consequently by market age of 20 weeks, toms reared under blue light in Experiment 1 showed a reduced BWG while there was no difference in Experiment 2 (Tables 14 and 16). However, by 24 weeks of age, the BWG for toms reared under blue lights in Experiment 2 was also significantly lower than the BWG for toms reared under red light. In addition, both LW nnd MW toms under blue light gained from 0.7 to 1.0 kg less than those under white or

Table 14 Male body weight gains (Kg) summarized over various growth periods by light color, light regimen and lines. (Experiment 1)

Treatment[1/]	4-10 Weeks (Kg)	4-16 Weeks (Kg)	4-20 Weeks (Kg)	4-24 Weeks (Kg)	16-24 Weeks (Kg)
Color					
White	2.9[a]	6.2[a]	8.5[a]	10.6[a]	4.4[a]
Red	2.9[a]	6.2[a]	8.5[a]	10.6[a]	4.4[a]
Blue	3.1[b]	6.5[b]	8.2[b]	9.9[b]	3.4[b]
Regimen					
2L:2D	3.0[a]	6.5[a]	8.6[a]	10.6[a]	4.2[a]
12L:12D	2.9[a]	6.2[b]	8.2[b]	10.1[b]	4.0[a]
Line					
LW	3.6[a]	7.5[a]	10.1[a]	12.5[a]	5.0[a]
MW	2.3[b]	5.1[b]	6.7[b]	8.3[b]	3.2[b]
Experimental Means	3.0	6.3	8.4	10.4	4.1

[1/] Means with each growth period and treatment subclass designated with different superscripts are significantly different ($P \leq 0.05$).

Table 15 Analyses of variance of male body weight gains by growth periods. (Experiment 1)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$)				
		4-10 Weeks	4-16 Weeks	4-20 Weeks	4-24 Weeks	16-24 Weeks
Color (C)	2	149.5**	216.4**	311.4*	1401.8**	2711.8**
Regimen (R)	1	63.0	552.1**	1292.7**	1465.2**	218.5
Line (L)	1	9016.0**	36506.7**	67435.5**	107230.5**	18603.2**
C X R	2	27.8	48.3	262.6*	248.5**	244.8
C X L	2	12.2	39.7	90.4	83.0	34.0
R X L	1	4.5	4.8	0.2	0.3	7.7
C X R X L	2	0.8	1.4	27.6	18.2	10.5
Error	12	19.4	28.1	51.6	33.5	73.2
Total	23					

* $P \leq 0.05$.
** $P \leq 0.01$.

Table 16 Male body weight gains (Kg) summarized over various growth periods by light color, light regimen, and lines. (Experiment 2)

Treatment[1/]	4-10 Weeks (Kg)	4-16 Weeks (Kg)	4-20 Weeks (Kg)	4-24 Weeks (Kg)	16-24 Weeks (Kg)
Color					
White	2.7^{a}	6.2^{a}	8.4^{a}	10.8^{ab}	4.6^{a}
Red	2.7^{a}	6.2^{a}	8.2^{a}	11.0^{a}	4.8^{a}
Blue	3.0^{b}	6.6^{b}	8.4^{a}	10.6^{b}	4.0^{b}
Regimen					
2L:2D	2.8^{a}	6.3^{a}	8.4^{a}	10.8^{a}	4.5^{a}
12L:12D	2.7^{b}	6.3^{a}	8.3^{a}	10.7^{a}	4.4^{a}
Line					
LW	3.4^{a}	7.5^{a}	9.9^{a}	12.7^{a}	5.3^{a}
MW	2.2^{b}	5.1^{b}	6.8^{b}	8.8^{b}	3.7^{b}
Experimental Means	2.8	6.3	8.3	10.8	4.5

1/ Means within each growth period and treatment subclass designated with different superscripts are significantly different ($P \leq 0.05$).

Table 17 Analyses of variance of male body weight gains by growth periods. (Experiment 2)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$)				
		4-10 Weeks	4-16 Weeks	4-20 Weeks	4-24 Weeks	16-24 Weeks
Color (C)	2	227.3**	337.8**	98.9	328.5*	1266.6**
Regimen (R)	1	45.1*	9.2	1.5	27.7	68.3
Line (L)	1	8425.4**	32783.4**	56396.0**	92630.1**	15200.4**
C X R	2	0.7	17.2	77.6	27.3	83.4
C X L	2	2.5	83.5	166.2	192.9	43.5
R X L	1	0.4	113.4	158.4	242.0*	24.1
C X R X L	2	4.6	9.7	5.3	78.0	122.6
Error	12	6.6	47.8	63.9	50.6	76.8
Total	23					

* $P \leq 0.05$.
** $P \leq 0.01$.

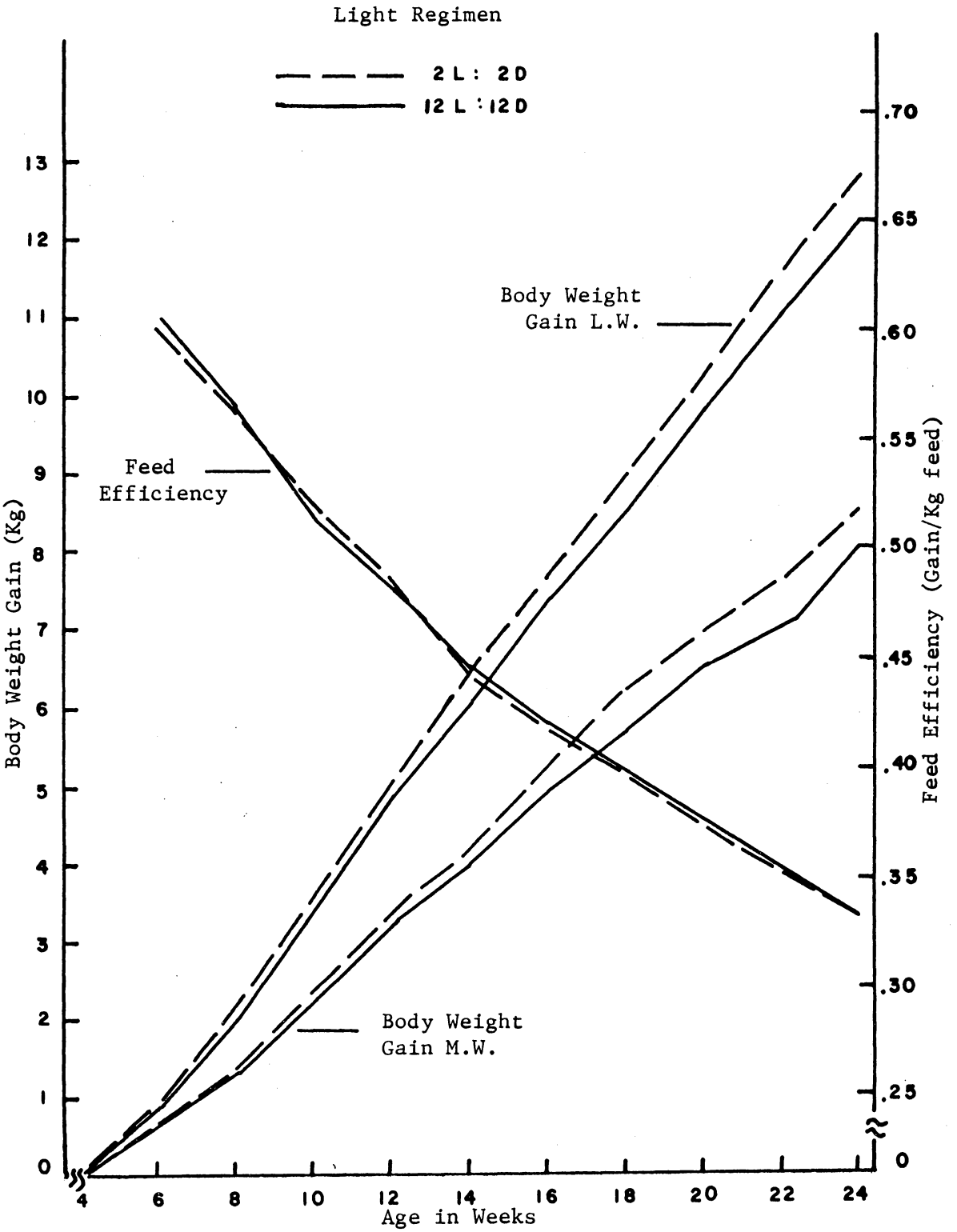

Figure 5. Body weight gain for L.W. and M.W. male lines and cumulative feed efficiency from 4 to 24 weeks of age by light regimen (Experiment 1)

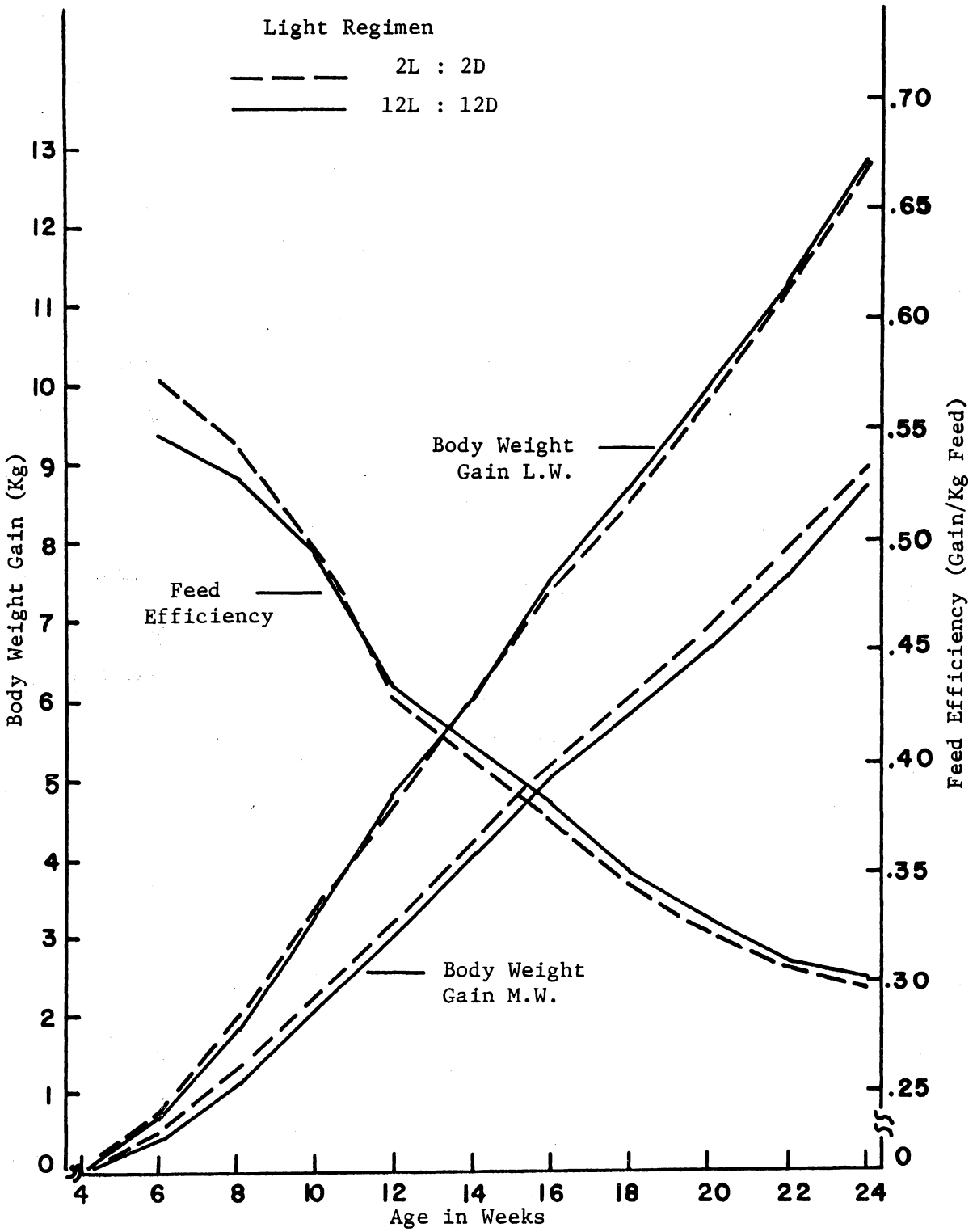

Figure 6. Body weight gain for L.W. and M.W. male lines and cumulative feed efficiency from 4 to 24 weeks of age by light regimen (Experiment 2)

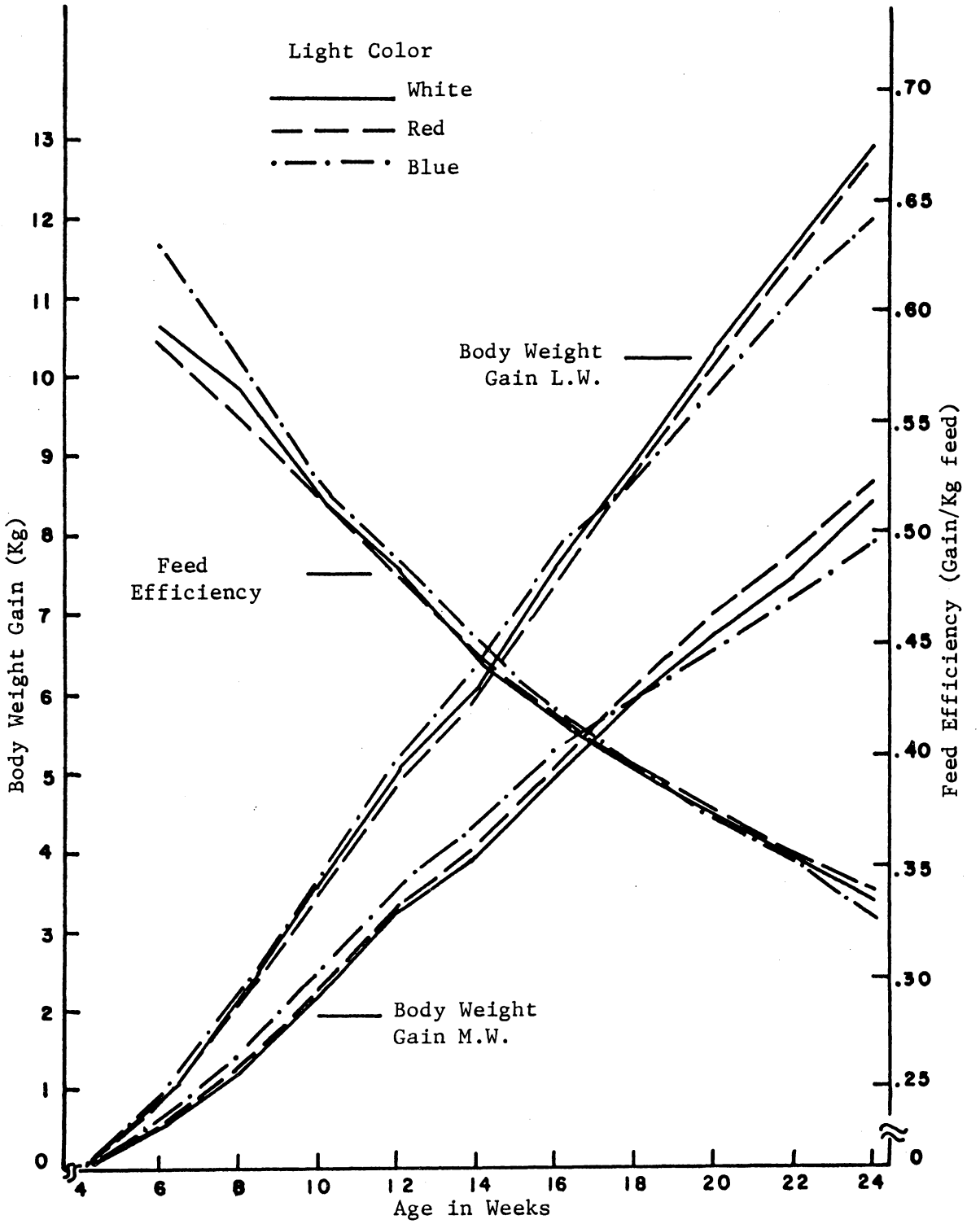

Figure 7. Body weight gain for L.W. and M.W. male lines and cumulative feed efficiency from 4 to 24 weeks of age by light color treatment (Experiment 1)

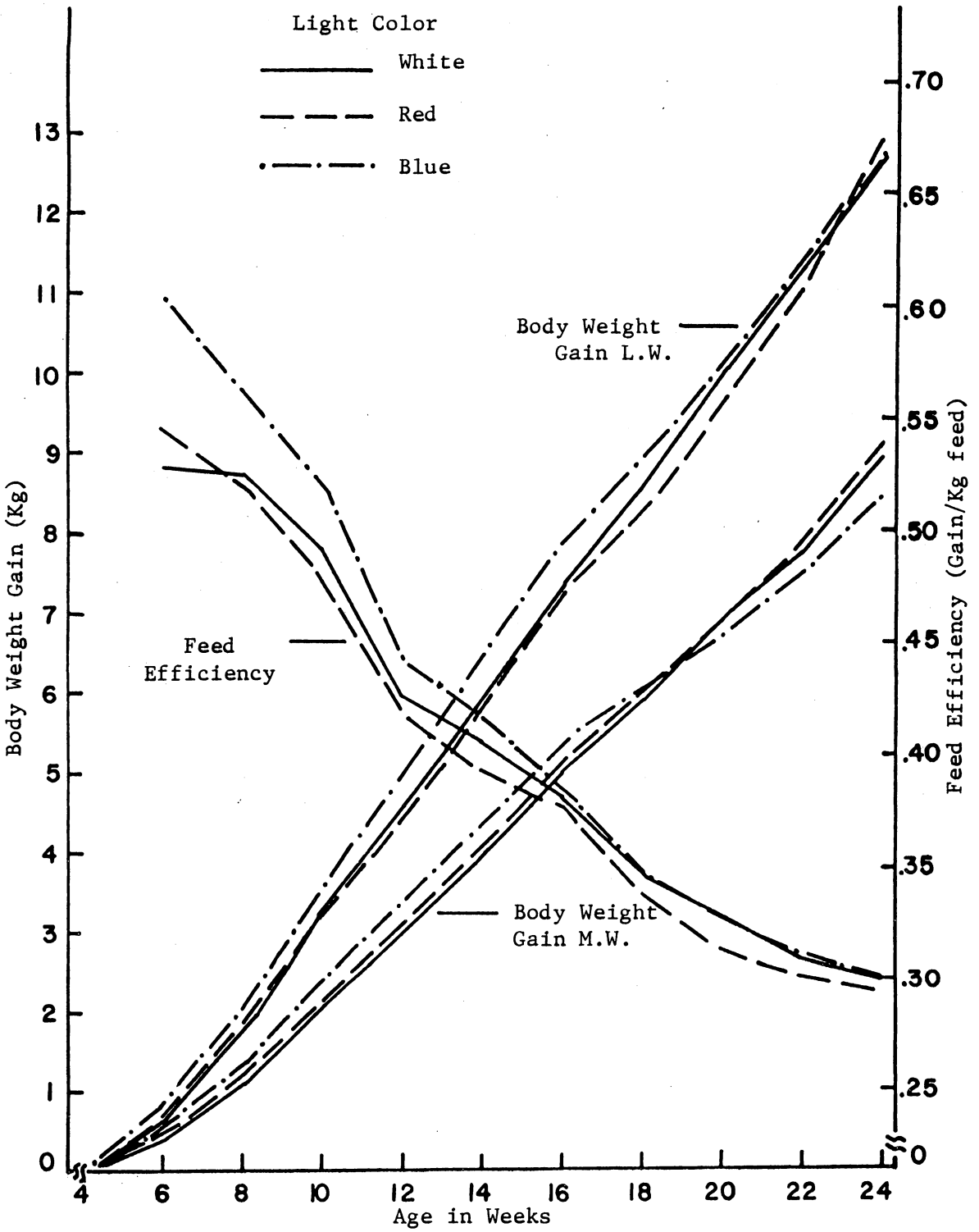

Figure 8. Body weight gain for L.W. and M.W. male lines and cumulative feed efficiency from 4 to 24 weeks of age by light color treatment (Experiment 2)

red lights during the period from 16-24 weeks (Tables 14 and 16).

Feed Efficiency

Although there was a slight trend to better feed efficiency under blue lights between 4 to 10 weeks (Figures 1-8) there were no significant differences due to any treatment at market age in Experiment 1 or 2 for either the males or females. The hens had an average feed efficiency in Experiment 1 of 0.366 at 18 weeks and of 0.309 by 24 weeks. In Experiment 2 the corresponding values were 0.330 and 0.276 respectively. Toms showed an average feed efficiency of 0.375 and 0.325 at 20 weeks and of 0.335 and 0.300 at 24 weeks for Experiments 1 and 2 respectively. The reduced feed efficiency in Experiment 2 was a reflection of the seasonal effect of cold weather since Experiment 2 was conducted during the fall and winter (September-February) while Experiment 1 was conducted during the spring and summer (March-August).

Mortality

The absolute and percentage mortality figures for females are presented by color, regimen and line in Tables 18 and 19 for Experiments 1 and 2. Due to the removal of LW poults to prevent overcrowding, the number of poults per pen had to be recalculated at 10 or 12 weeks. Therefore, mortality figures and percentages were calculated from 4 to 10 or 12 weeks of age depending upon the experiment. Late mortality was calculated on the number of birds per pen at 10 or 12 weeks and covers the period from 10 or 12 weeks to market age and to 24 weeks of age. In both experiments, early mortality up to 10 or 12 weeks appears to be slightly higher under blue light. Mortality to market age appeared to be slightly less under blue light and for MW hens in both experiments.

Table 18 Summary of female mortality from 4-10, 10-18, and 10-24 weeks of age by lines, light color and light regimen. (Experiment 1)

Treatment	Number Poults Started at 4 wks	Mortality From 4-10 wks	Percent Mortality 4-10 wks	Number Poults 10 wks[1]	Mortality From 10-18 wks	Percent Mortality From 10-18 wks	Mortality From 10-24 wks	Percent Mortality From 10-24 wks
Color								
White	308	1	0.3	220	6	2.7	11	5.0
Red	308	2	0.6	218	5	2.3	7	3.2
Blue	308	6	1.9	220	3	1.4	4	1.8
Regimen								
2L:2D	462	6	1.3	330	9	2.7	12	3.6
12L:12D	462	3	0.6	328	5	0.2	10	3.0
Line								
LW	576	6	1.0	324	9	2.8	15	4.6
MW	348	3	0.9	334	5	1.5	7	2.1
Experimental Total	924	9	1.0	658	14	2.1	22	3.3

[1] The number of LW turkeys per pen was reduced at 10 weeks of age to increase floor space per bird and prevent stress due to crowding.

Table 19 Summary of female mortality from 4-12, 12-18 and 12-24 weeks of age by line, light color and light regimen. (Experiment 2)

Treatment	Number Poults Started at 4 wks	Mortality From 4-12 wks	Percent Mortality 4-12 wks	Number Poults 12 wks	Mortality From 12-18 wks	Percent Mortality From 12-18 wks	Mortality From 12-24 wks	Percent Mortality From 12-24 wks
Color								
White	260	13	5.0	169	6	3.6	15	8.9
Red	260	6	2.3	173	4	2.3	6	3.5
Blue	260	17	6.5	166	3	1.8	4	2.4
Regimen								
2L:2D	390	18	4.6	254	6	2.4	12	4.7
12L:12D	390	18	4.6	254	7	2.6	13	5.1
Line								
LW	480	20	4.2	233	9	3.9	15	6.4
MW	300	16	5.3	275	4	1.4	10	3.6
Experimental Total	780	36	4.6 -	508	13	2.6	25	4.9

[1] The number of LW turkeys per pen was reduced at 12 weeks of age to increase floor space per bird and prevent stress due to crowding.

Table 20 Summary of male mortality from 4-10, 10-20 and 10-24 weeks of age by line, light color, and light regimen. (Experiment 1)

Treatment	Number Poults Started at 4 wks	Mortality From 4-10 wks	Percent Mortality 4-10 wks	Number Poults 10 wks[1]	Mortality From 10-20 wks	Percent Mortality From 10-20 wks	Mortality From 10-24 wks	Percent Mortality From 10-24 wks
Color								
White	304	7	2.3	211	13	6.2	18	8.5
Red	304	3	1.0	215	10	4.7	14	6.5
Blue	304	16	5.1	211	3	1.4	8	3.8
Regimen								
2L:2D	456	16	3.5	319	14	4.4	20	6.3
12L:12D	456	10	2.2	318	12	3.8	20	6.3
Line								
LW	576	16	2.8	323	20	6.2	30	9.3
MW	336	10	3.0	314	6	1.9	10	3.2
Experimental Total	912	26	2.9	637	26	4.1	40	6.3

[1] The number of LW turkeys per pen was reduced at 10 weeks of age to increase floor space per bird and prevent stress due to crowding.

Table 21 Summary of male mortality from 4-12, 12-20 and 12-24 weeks of age by line, light color and light regimen. (Experiment 2)

Treatment	Number Poults Started at 4 wks	Mortality From 4-12 wks	Percent Mortality From 4-12 wks	Number Poults 12 wks[1]	Mortality From 12-20 wks	Percent Mortality From 12-20 wks	Mortality From 12-24 wks	Percent Mortality From 12-24 wks
Color								
White	260	19	7.3	165	21	12.7	26	15.8
Red	260	9	3.5	172	10	5.8	13	7.6
Blue	260	21	8.1	160	12	7.5	14	8.8
Regimen								
2L:2D	390	20	5.1	243	19	7.8	24	9.9
12L:12D	390	19	4.9	254	24	9.4	29	11.4
Line								
LW	480	24	5.0	237	32	13.5	40	16.9
MW	300	25	8.3	260	11	4.2	13	5.0
Experimental Total	780	49	6.3	497	43	8.7	53	10.7

[1] The number of LW turkeys per pen was reduced at 12 weeks of age to increase floor space and prevent stress due to crowding.

The trend was even more pronounced by 24 weeks of age where the mortality values under blue lights were from 3.2 to 6.5% lower than that observed under white lights.

Data for mortality for male turkeys is presented in Tables 20 and 21 for Experiment 1 and 2 respectively. Early mortality followed the same trend observed for females with the highest mortality occurring under blue light. Later mortality to market age (20 weeks) was lowest under blue lights and for the MW line. By 24 weeks of age, mortality for toms reared under blue lights was two times lower than under white lights. It was also three times lower for the MW than for the LW males. Light regimen did not seem to show any consistant or marked effect on mortality.

Live Grade and Feather Score

The females were live graded and scored for feather condition at 20 weeks of age. The results are tabulated in Tables 22 and 23 by color, regimen and line. Analyses of variance on the percent Grade A's (Table 24) showed no treatment effect in either experiment. Feather score was significantly lowered for birds reared under white light in both experiments. In Experiment 2, hens reared on the diurnal schedule averaged 10% lower feather scores than those on the intermittent cycle. However, this reduced feather score under diurnal light was only valid for birds reared under white light as indicated by the significant color by regimen interaction in both experiments. Under white light, diurnal feather scores ranged from 7 to 28% lower than those under the intermittent regimen. Hens under the red and blue light showed almost the same feather scores under the diurnal as under the intermittent light regimens.

Table 22 Percentage of females at 20 weeks of age with live market grades of A,B,C or reject and feather scores of 1,2,3 or 4 by light color, light regimen and by lines. (Experiment 1)

Treatment	Grade				Feather Score			
	A[1/]	B	C	Reject	1[1/]	2	3	4
Color								
White	97.3[a]	1.0	1.7	0	92.4[a]	6.6	0.5	0.6
Red	99.5[a]	0.5	0	0	100.0[b]	0	0	0
Blue	98.9[a]	1.1	0	0	100.0[b]	0	0	0
Regimen								
2L:2D	97.4[a]	1.8	0.8	0	98.5[a]	1.5	0	0
12L:12D	99.6[a]	0	0.4	0	96.4[a]	2.9	0.3	0.4
Line								
LW	98.2[a]	1.1	0.7	0	96.5[a]	2.8	0.3	0.4
MW	98.9[a]	0.7	0.4	0	98.4[a]	1.6	0	0
Experimental Means	98.5	0.9	0.6	0	97.5	2.2	0.2	0.2

1/ Means within each treatment having different superscripts are significantly different. ($P \leq 0.05$)

Table 23 Percentage of females at 20 weeks of age with live market grades of A,B,C or reject and feather scores of 1,2,3 or 4 by light color, light regimen and by lines. (Experiment 2)

Treatment	Grade				Feather Score			
	A[1/]	B	C	Reject	1[1/]	2	3	4
Color								
White	98.7[a]	0.7	0.6	0	82.5[a]	17.0	0.6	0
Red	98.7[a]	1.3	0	0	98.0[b]	2.0	0	0
Blue	98.7[a]	1.3	0	0	100.0[b]	0	0	0
Regimen								
2L:2D	99.2[a]	0.4	0.4	0	98.5[a]	1.1	0.4	0
12L:12D	98.2[a]	1.8	0	0	88.5[b]	11.6	0	0
Line								
LW	98.7[a]	0.9	0.4	0	95.7[a]	3.9	0.4	0
MW	98.7[a]	1.3	0	0	91.3[a]	8.7	0	0
Experimental Means	98.7	1.1	0.2	0	93.5	6.3	0.2	0

1/ Means within each treatment which have different superscripts are significantly different. ($P \leq 0.05$)

Table 24 Analyses of variance of the percentage of females which graded A and the percentage with a feather score of 1. (Experiments 1 and 2)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$)[1/] Experiment 1 Grade A	Experiment 1 Feather Score 1	Experiment 2 Grade A	Experiment 2 Feather Score 1
Color (c)	2	19.8	320.2**	0.2	720.7**
Regimen (R)	1	78.7	57.1	20.5	501.3*
Line (L)	1	0.3	11.1	0.7	50.5
C X R	2	4.2	58.5*	16.9	360.4*
C X L	2	13.4	11.0	0.4	27.7
R X L	1	8.5	34.6	0.2	177.3
C X R X L	2	2.8	33.6	50.2	95.5
Error	12	27.2	13.1	22.2	85.4
Total	23				

[1/] Weighted arcsin transformation values.
* $P \leq 0.05$
** $P \leq 0.01$

Table 25 Percentage of males at 24 weeks of age with live market grades of A,B,C or reject and feather scores of 1,2,3 or 4 by light color, light regimen and by lines. (Experiment 1)

Treatment	Grade				Feather Score			
	A[1/]	B	C	Reject	1[1/]	2	3	4
Color								
White	95.9[a]	4.1	0	0	97.3[a]	2.7	0	0
Red	97.4[a]	2.6	0	0	99.5[a]	0.5	0	0
Blue	97.8[a]	2.2	0	0	99.4[a]	0.6	0	0
Regimen								
2L:2D	96.1[a]	3.9	0	0	99.6[a]	0.4	0	0
12L:12D	97.9[a]	2.1	0	0	97.9[a]	2.1	0	0
Line								
LW	96.6[a]	3.4	0	0	98.4[a]	1.6	0	0
MW	97.5[a]	2.5	0	00	99.1[a]	0.9	0	0
Experimental Means	97.0	3.0	0	0	98.8	1.3	0	0

1/ Means within each treatment having different superscripts are significantly different. ($P \leq 0.05$)

Table 26 Percentage of males at 24 weeks of age with live market grades of A,B,C or reject and feather scores of 1,2,3 or 4 by light color, light regimen and by lines. (Experiment 2)

Treatment	Grade				Feather Score			
	A[1/]	B	C	Reject	1[1/]	2	3	4
Color								
White	94.2[a]	4.7	1.1	0	77.3[a]	22.7	0	0
Red	92.6[a]	6.6	0.8	0	97.1[b]	2.9	0	0
Blue	95.9[a]	4.1	0	0	99.4[b]	0.6	0	0
Regimen								
2L:2D	93.5[a]	5.2	1.3	0	96.8[a]	3.2	0	0
12L:12D	95.0[a]	5.0	0	0	85.7[a]	14.3	0	0
Line								
LW	90.3[a]	8.4	1.3	0	90.8[a]	9.2	0	0
MW	98.2[b]	1.9	0	0	91.7[a]	8.3	0	0
Experimental Means	94.2	5.1	0.6	0	91.3	8.7	0	0

1/ Means within each treatment having different superscripts are significantly different. ($P \leq 0.05$)

Table 27 Analyses of variance of the percentage of males which graded A and the percentage with a feather score of 1. (Experiment 1 and 2)

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$) 1/ Experiment 1 Grade A	Experiment 1 Feather Score 1	Experiment 2 Grade A	Experiment 2 Feather Score 1
Color (C)	2	25.4	21.5	7.6	922.7*
Regimen (R)	1	72.4	40.7	2.0	408.1
Line (L)	1	27.8	6.8	604.2**	43.4
C X R	2	19.7	54.8	274.7*	557.0*
C X L	2	14.9	12.6	51.1	31.2
R X L	1	2.7	6.9	64.8	9.6
C X R X L	2	56.2	10.1	96.3	51.9
Error	12	26.7	29.0	45.1	136.3
Total	23				

1/ Weighted arcsin transformations values.
* $P \leq 0.05$
** $P \leq 0.01$

Although there was a slight trend shown in Table 25 toward lower grade and feather scores under white light, the differences were not significant (Table 27) for males at 24 weeks of age in Experiment 1. However, in Experiment 2 (Table 26), as shown earlier with the females, feather score was significantly ($P \leq 0.05$) reduced under the white light environment. In addition, in Experiment 2, the LW lines had 8% fewer grade A's than the MW line ($P \leq 0.05$).

The color by regimen interactions were significant for both grade and feather scores (Table 27) in Experiment 2. For feather scores this reflected the same pattern as seen in the females. The number of toms with a feather score of 1 was 34% lower under the white diurnal regimen compared to those under the white intermittent regimen; there was only a 3% difference between the red and blue regimens. The Grade interaction was slightly more complex with the percent Grade A's being 6-8% lower under white or red intermittent but being 9% lower under the blue diurnal regimen.

Necropsy Data

Birds of both sexes were necropsied at 18 and 24 weeks in Experiment 1 and 2. The data on the female gland weights were adjusted for body weight, i.e. milligrams per kilogram of body weight and are presented along with the hematocrit values in Tables 28-31. These data were analysed by multivariate analyses (Kramer, 1972). The U-statistics for the analyses are given in Table 32. The only significant effect was a difference between the LW and MW birds at 18 weeks in Experiment 1 and at 24 weeks in Experiments 1 and 2. There was a trend for all gland weights except for the ovaries to be heavier in MW on a mg/kg basis at all ages. However, using simultaneous confidence intervals to make

Table 28 Pituitary, pineal, right adrenal, left adrenal, ovary weight, oviduct weight in mg/kg of body weight, and average hematocrit for females necropsied at 18 weeks of age by light color, regimen and lines. (Experiment 1)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Ovary Weight mg/kg	Oviduct Weight mg/kg	Hematocrit
Color							
White	2.5	2.6	17.7	15.2	202.5	99.2	38.0
Red	2.9	2.8	18.7	17.8	196.2	91.9	36.6
Blue	3.3	3.0	15.0	13.3	157.5	70.8	40.3
Regimen							
2L:2D	2.5	2.5	16.5	15.0	211.7	93.8	38.2
12L:12D	2.6	3.0	17.8	15.9	159.1	80.8	38.4
Line							
LW	2.1	2.6	14.1	13.0	194.9	80.8	38.6
MW	3.0	3.0	20.2	17.9	175.9	93.8	38.0
Experimental Means	2.5	2.8	17.1	15.4	185.4	87.3	38.2

Table 29 Pituitary, pineal, right adrenal, left adrenal, ovary weight, oviduct weight in mg/kg of body weight, and average hematocrit for females necropsied at 18 weeks of age by light color, regimen and lines. (Experiment 2)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Ovary Weight mg/kg	Oviduct Weight mg/kg	Hematocrit
Color							
White	2.0	2.0	17.7	15.0	201.6	62.1	38.6
Red	2.2	2.3	17.6	15.2	211.3	90.3	38.2
Blue	1.9	2.4	18.1	15.3	137.4	55.2	39.1
Regimen							
2L:2D	2.2	2.4	17.2	15.4	190.0	77.9	38.7
12L:12D	1.9	2.1	18.4	15.0	176.8	60.5	38.6
Line							
LW	1.7	2.1	15.7	13.4	181.1	65.0	39.6
MW	2.4	2.4	19.9	17.0	185.7	73.4	37.7
Experimental Means	2.1	2.3	17.8	15.2	183.42	69.2	38.6

Table 30 Pituitary, pineal, right adrenal, left adrenal, ovary weight, oviduct weight in mg/kg of body weight, and average hematocrit for females necropsied at 24 weeks of age by light color, regimen and lines. (Experiment 1)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Ovary Weight mg/kg	Oviduct Weight mg/kg	Hematocrit
Color							
White	2.1	1.8	15.0	13.5	319.2	395.2	38.4
Red	2.3	1.9	14.0	12.0	354.9	286.3	38.3
Blue	1.7	2.0	13.7	13.1	213.4	128.3	39.8
Regimen							
2L:2D	1.8	1.9	14.0	12.4	263.0	227.7	38.9
12L:12D	2.2	1.9	14.5	13.3	328.7	312.2	38.8
Line							
LW	1.7	1.7	11.4	11.7	320.7	251.0	38.6
MW	2.3	2.1	17.1	14.0	271.0	288.9	39.1
Experimental Means	2.0	1.9	14.2	12.9	295.8	269.9	38.9

Table 31 Pituitary, pineal, right adrenal, left adrenal, ovary weight, oviduct weight in mg/kg of body weight, and average hematocrit for females necropsied at 24 weeks of age by light color, regimen and lines. (Experiment 2)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Ovary Weight mg/kg	Oviduct Weight mg/kg	Hematocrit
Color							
White	2.3	2.4	16.2	14.9	318.9	136.1	38.4
Red	2.0	2.1	14.7	14.8	320.7	186.4	38.8
Blue	1.6	2.5	15.0	12.6	175.7	66.7	42.0
Regimen							
2L:2D	2.0	2.3	15.2	14.0	254.6	109.0	40.0
12L:12D	2.0	2.3	15.4	14.2	289.0	150.5	39.5
Line							
LW	1.6	1.9	12.6	11.8	289.7	121.5	40.3
MW	2.3	2.8	18.1	16.4	253.8	138.0	39.2
Experimental Means	2.0	2.3	15.3	14.1	271.8	129.7	39.7

Table 32 Multivariate analyses of the female necropsy data at 18 and 24 weeks. (Experiment 1 and 2)

Source of Variation	Degrees of Freedom	Critical Value[1] U-Tables (0.05)	U-Statistics [2] Experiment 1 18 Wks	Experiment 1 24 Wks	Experiment 2 18 Wks	Experiment 2 24 Wks
Color (C)	2	0.060396	0.06067	0.20088	0.11366	0.08401
Regimen (R)	1	0.169506	0.56271	0.56014	0.27248	0.86249
Line (L)	1	0.169506	0.09724*	0.09912*	0.32738	0.11448*
C X R	2	0.060396	0.19913	0.19003	0.36573	0.24065
C X L	2	0.060396	0.32147	0.16197	0.14493	0.12840
R X L	1	0.169506	0.52977	0.66590	0.36963	0.20939
C X R X L	2	0.060396	0.33548	0.29113	0.18099	0.22253
Error	12					

1/ Critical values - taken from U-Statistics Tables Kramer (1972) page 293, where P=7, V_H=1 or 2, V_E=12.

2/ *U-statistic is significant if it is less than the critical value.

comparisons between each of the factors measured revealed no significant differences for any of the factors individually. This indicates that the line differences were very subtle and become apparent only when viewed cumulatively.

There were, however, some persistant trends in the color and regimen data. The ovary and oviduct weights at 18 weeks (Tables 28 and 29) were heavier for the intermittent (2L:2D) than for the diurnal regimen. But at 24 weeks of age (Tables 30 and 31) the opposite order was found in both experiments. An even larger and more persistant trend was noted when ovary and oviduct weights were compared for birds reared under white, red or blue lights. Ovary weights averaged 27% lower at 18 weeks of age and 41% lower at 24 weeks of age from hens reared under blue light as compared to those reared under red or white light. Similarly, oviducts from hens under blue lights weighed 28% less at 18 weeks and 60% less at 24 weeks than those from the white or red light environments.

The ovaries responded in the same way to all factors in both Experiments 1 and 2. Mean ovary weights were slightly less in Experiment 2 mainly due to a greater supression of ovary weight under the blue lights.

At 18 weeks of age the oviduct weights followed the same weight pattern in both experiments except for an unaccountable suppression under white light in Experiment 2. A notable difference in oviduct weights occurred between experiments at 24 weeks of age. The oviducts from hens in Experiment 1 averaged twice the size of those in Experiment 2 regardless of treatment. This could indicate a seasonal difference and that the hens in Experiment 2 were not as sexually mature at 24 weeks as those in Experiment 1.

The gland weights of males adjusted for body weight, hematocrit values and the testes histological measurements are presented in Tables 33-36. These data were also analysed using the multivariate analyses (Krammer, 1972). The U-test values are presented in Table 37. At 24 weeks in Experiment 1 the males also showed a significant difference ($P \leq 0.05$) between the LW and MW lines. Again the simultaneous confidence interval tests revealed no specific differences. Similarly, although significant ($P \leq 0.05$) overall differences between the color treatments were detected at 24 weeks of age in Experiment 2, simultaneous confidence interval comparison revealed no specific differences. At 18 weeks in Experiment 2 all sources of variation but the color by regimen interaction appeared significant. Most of the interaction effects can be attributed to the LW toms reared under white intermittent lights. These toms had an average testes weight of 1041.7 mg/kg, average testes stage of development of 5.35, and average tubule diameters of 167.4 microns. These values indicated a much greater sexual development than other groups, especially if compared to the corresponding experimental means of 498.86 mg/kg, 3.78 and 127.41 microns. The significant color by line interaction was due to this highly advanced sexual maturity of the LW's under white light while the MW line toms reared under red and blue lights showed greater testes measurement values. The regimen by line interaction was not so clearly defined and appeared to be due to interaction in the pineal, left adrenal and testes weight and the stage of testes development. The presence of the significant interactions precluded the use of simultaneous confidence interval comparisons of the individual factors within the main effects.

Table 33 Pituitary, pineal, right adrenal, left adrenal and combined testes weights in mg/kg of body weight, and average hematocrit, stage of testes development and diameter of seminiferous tubules (micron-μ) for males necropsied at 18 weeks of age by light color, regimen and line. (Experiment 1)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Combined Testes mg/kg	Average Testicular Stage	Average Seminiferous Tubule Diameter (u)	Hema-tocrit
Color								
White	2.5	2.3	15.7	14.4	733.0	3.7	155.7	35.4
Red	2.6	1.9	16.6	14.2	242.5	2.5	91.2	36.4
Blue	2.2	2.1	17.9	14.5	349.8	3.1	109.5	38.3
Regimen								
2L:2D	2.5	2.1	16.1	14.2	440.7	2.8	112.4	35.7
12L:12D	2.3	2.0	17.3	14.3	442.9	3.4	125.2	37.8
Line								
LW	2.1	1.9	15.6	13.7	465.7	3.2	123.6	36.3
MW	2.7	2.3	17.9	15.0	417.9	3.0	114.0	37.1
Experimental Means	2.4	2.1	16.7	14.4	441.8	3.1	118.8	36.7

Table 34 Pituitary, pineal, right adrenal, left adrenal and combined testes weights in mg/kg of body weight, and average hematocrit, stage of testes development and diameter of seminiferous tubules (microns-μ) for males necropsied at 18 weeks of age by light color, regimen and line. (Experiment 2)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Combined Testes mg/kg	Average Testicular Stage	Average Seminiferous Tubule Diameter (u)	Hematocrit
Color								
White	2.8	2.0	23.9	21.3	597.4	4.6	158.4	41.6
Red	2.6	2.1	22.3	18.8	509.5	3.3	115.7	38.9
Blue	1.8	2.1	20.1	17.1	391.7	3.5	108.2	39.3
Regimen								
2L:2D	2.5	2.1	21.7	18.7	572.4	3.6	124.6	40.3
12L:12D	2.3	2.0	22.5	19.4	425.3	4.0	130.2	39.3
Line								
LW	2.0	1.7	20.0	16.4	418.9	3.5	108.2	40.1
MW	2.9	2.5	24.2	21.6	578.8	4.1	146.6	39.5
Experimental Means	2.4	2.1	22.1	19.1	498.9	3.8	127.4	39.8

Table 35 Pituitary, pineal, right adrenal, left adrenal and combined testes weights in mg/kg of body weight, and average hematocrit, stage of testes development and diameter of seminiferous tubules (microns-μ) for males necropsied at 24 weeks of age by light color, regimen and line. (Experiment 1)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Combined Testes mg/kg	Average Testicular Stage	Average Seminiferous Tubule Diameter (u)	Hematocrit
Color								
White	2.2	1.4	18.1	15.6	1372.5	5.0	211.6	38.8
Red	2.0	1.5	17.1	14.3	1824.9	5.6	208.4	38.4
Blue	1.8	1.8	15.5	11.8	637.3	3.9	131.6	39.3
Regimen								
2L:2D	2.2	1.6	17.3	14.6	1416.0	5.0	195.8	38.3
12L:12D	1.8	1.6	16.5	13.2	1140.4	4.6	172.8	39.3
Line								
LW	1.7	1.3	14.0	11.6	1706.5	4.9	184.9	39.1
MW	2.3	1.8	19.9	16.2	849.9	4.7	182.9	38.5
Experimental Means	2.0	1.6	16.9	13.9	1278.2	4.8	183.9	38.8

Table 36 Pituitary, pineal, right adrenal, left adrenal and combined testes weights in mg/kg of body weight, and average hematocrit, stage of testes development and diameter of seminiferous tubules (microns-μ) for males necropsied at 24 weeks of age by light color, regimen and line. (Experiment 2)

Treatment	Pituitary mg/kg	Pineal mg/kg	Right Adrenal mg/kg	Left Adrenal mg/kg	Combined Testes mg/kg	Average Testicular Stage	Average Seminiferous Tubule Diameter (u)	Hema-tocrit
Color								
White	1.5	1.4	15.0	13.9	1692.4	5.6	223.8	38.4
Red	1.9	1.4	16.4	15.6	2002.8	5.5	212.6	43.3
Blue	1.4	1.8	14.7	13.3	650.6	3.8	132.3	42.3
Regimen								
2L:2D	1.5	1.4	14.9	14.1	1615.6	5.4	210.1	41.7
12L:12D	1.7	1.7	15.8	14.5	1281.5	4.5	169.0	41.0
Line								
LW	1.5	1.3	13.3	11.9	1479.3	5.1	199.3	42.1
MW	1.7	1.8	17.4	16.7	1417.8	4.8	179.8	40.5
Experimental Means	1.6	1.5	15.4	14.3	1448.5	4.9	189.6	41.3

Table 37 Multivariate analyses of the male necropsy data at 18 and 24 weeks. (Experiment 1 and 2)

Source of Variation	Degrees of Freedom	Critical Value[1] (0.05)	U-Statistics[2]			
			Experiment 1		Experiment 2	
			18 Wks	24 Wks	18 Wks	24 Wks
Color (C)	2	0.033314	0.05817	0.06804	0.02568*	0.00582*
Regimen (R)	1	0.115676	0.23322	0.32135	0.094604*	0.60916
Line (L)	1	0.115676	0.32918	0.06202*	0.06022*	0.16632
C X R	2	0.033314	0.08893	0.114389	0.04473	0.11113
C X L	2	0.033314	0.14028	0.07008	0.01167*	0.12041
R X L	1	0.115676	0.73006	0.13521	0.11137*	0.15371
C X R X L	2	0.033314	0.33503	0.05762	0.02386*	0.06318
Error	12					

[1] Critical values taken from tables by Kramer (1972) page 295 where P=8, V_H=1 or 2, V_E=12.

[2] *U-statistic is significant at the 0.05 level if it is less than the critical value.

Again, as with the females, there was a trend to retarded sexual development under blue light as indicated by the smaller testes weights, testes stage of development and seminiferous tubule diameter values presented in Tables 33-36.

It was interesting to compare the changes for the color by regimen interactions from 18 weeks to 24 weeks of age for the three testes measurements. Those changes are presented in Figures 9 and 10 for Experiment 1 and 2. While the testes values for the white, and more so the white intermittent regimen were greatest at 18 weeks of age, by 24 weeks of age birds under red light seem to have received some extra sexual stimulation and exceeded the white light groups. In general the response under blue light was much less than that observed under white or red light. However, the response change with age under blue diurnal light varied markedly from the response under the blue intermittent regimen. Under blue intermittent light testes measurements increased from 18 to 24 weeks of age as they did under all red and white regimens. However, under blue diurnal light all testes values in both experiments showed a slight decline from 18 to 24 weeks of age.

Blood Plasma Androgens

Blood plasma samples were analysed by competitive protein binding technique for androgen levels. The LW and MW lines were statistically analysed separately as the blood samples were drawn at two different times in the day.

The androgen levels at 18 and 24 weeks for both lines are presented in Tables 38 and 40 for Experiment 1 and 2. The analyses of variance are presented in Tables 39 and 41. No significant differences

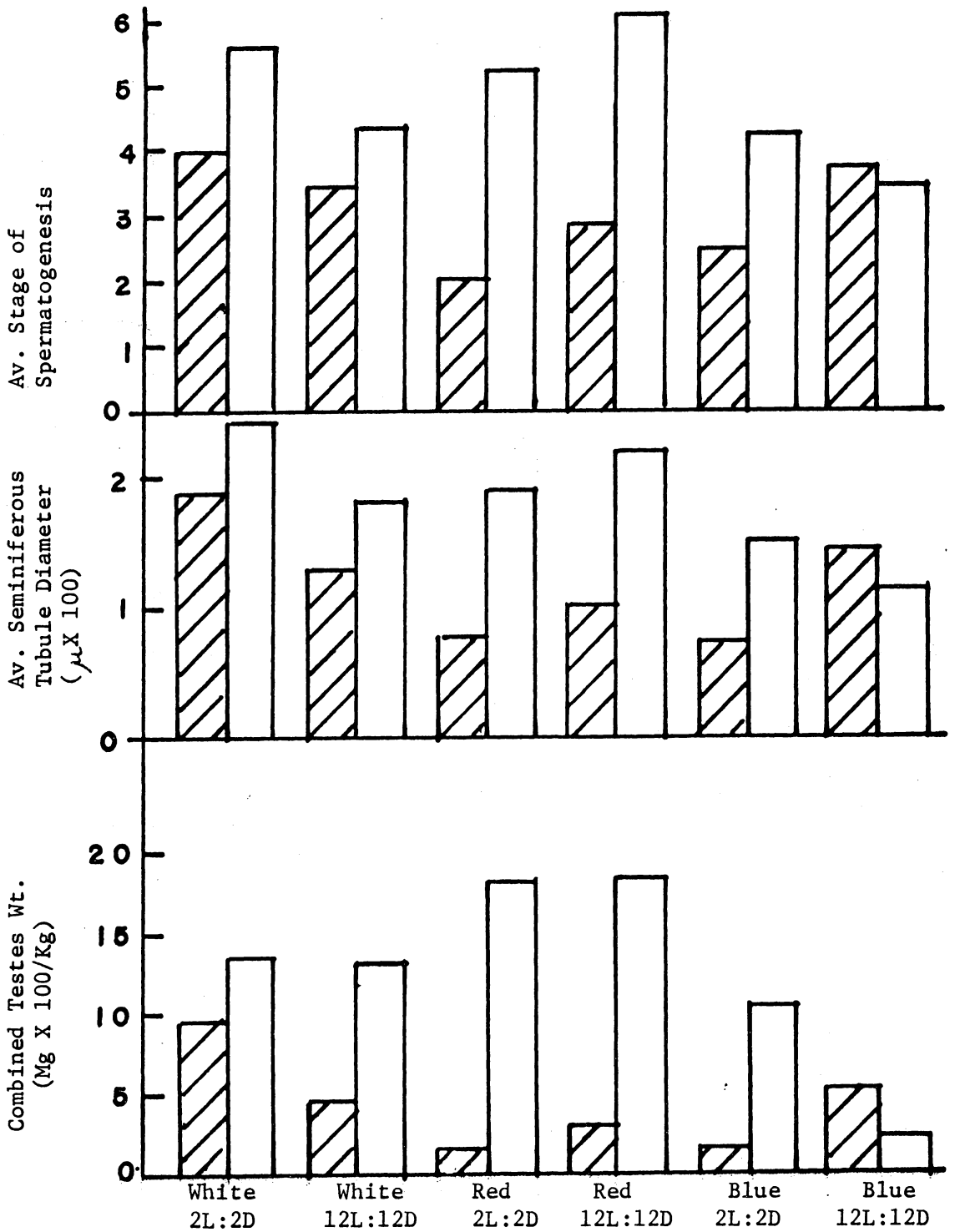

Figure 9. Combined weight of both testes, average diameters of the seminiferous tubules, and average stage of spermatogenesis compared for each light color - light regimen combination at 18 (shaded bars) and 24 (open bars) weeks of age. (Experiment 1)

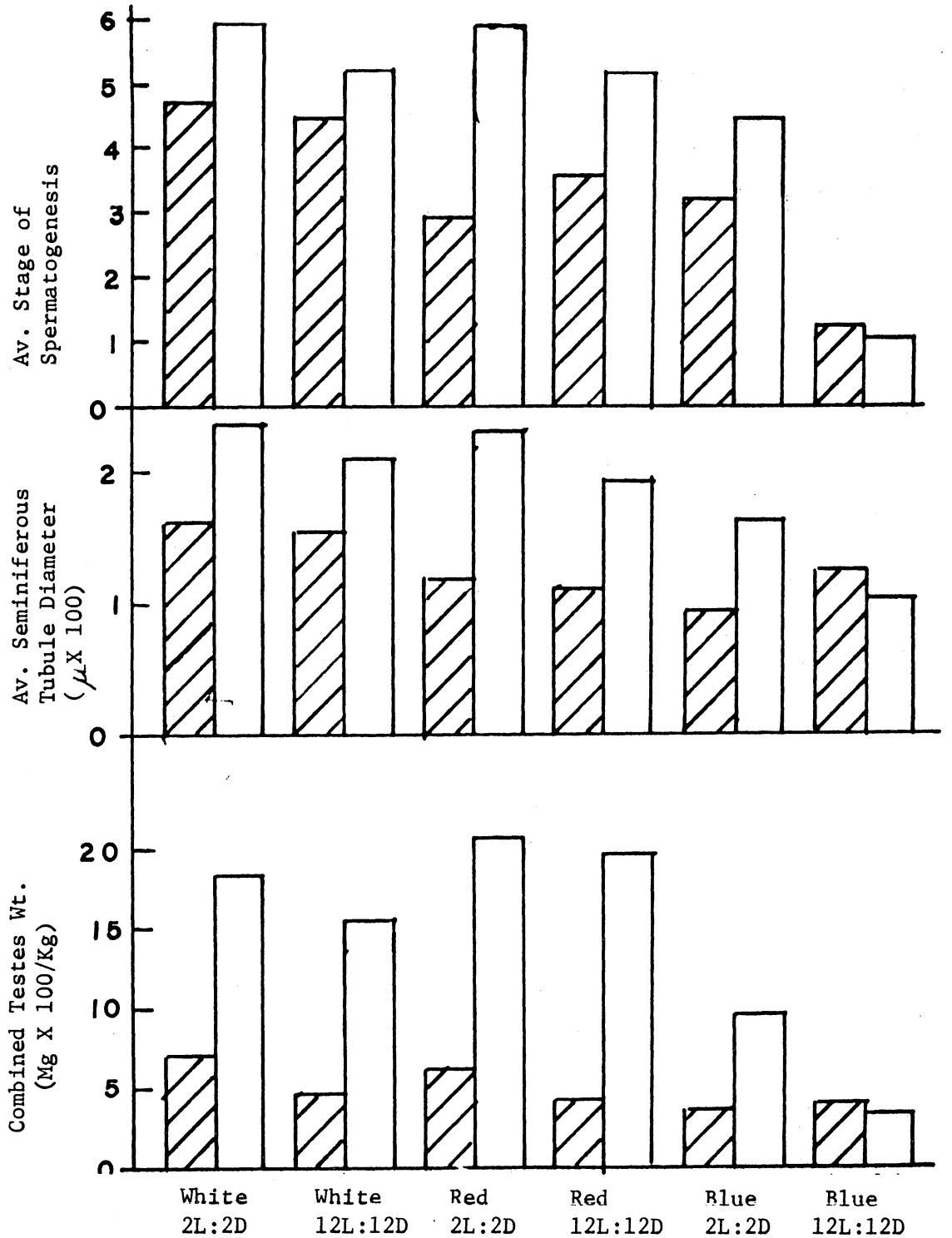

Figure 10. Combined weight of both testes, average diameters of the seminferous tubules, and average stage of spermatogenesis compared for each light color - light regimen combination at 18 (shaded bars) and 24 (open bars) weeks of age (Experiment 2)

Table 38 Androgen levels (ng/ml) in plasma from LW and MW male turkeys 18 and 24-weeks of age by light color and regimen (Experiment 1).[1/]

Treatment	LW Males		MW Males	
	18 Wks ng/ml	24 Wks ng/ml	18 Wks ng/ml	24 Wks ng/ml
Color				
White	1.10	3.31	1.07	4.09
Red	1.66	5.23	0.96	2.82
Blue	2.81	4.26	1.38	1.94
Regimen				
2L:2D	0.90	4.81	1.46	2.69
12L:12D	2.82	3.73	0.82	3.21
Experimental Means	1.86	4.27	1.38	2.95

[1/] Androgen levels are presented and analysed by lines because the blood samples per line were drawn at two different times of the day.

Table 39 Analyses of variance for plasma androgen levels in male turkeys at 18 and 24 weeks of age (Experiment 1)

Source of Variation	Degrees of Freedom	LW Males		MW Males	
		18 Wks	24 Wks	18 Wks	24 Wks
Color (C)	2	6.09	7.34	0.38	9.33
Regimen (R)	1	22.15	6.98	2.52	1.63
C X R	2	17.10	20.49	2.00	14.28
Experimental Error	6	87.70	11.94	1.81	6.01
Sampling Error	12	2.35	0.43	0.39	0.41
Total	23				

Table 40 Androgen levels (ng/ml) in plasma from LW and MW male turkeys at 18 and 24 weeks of age by light color and regimen. (Experiment 2)[1/]

Treatment	LW Males		MW Males	
	18 Wks ng/ml	24 Wks ng/ml	18 Wks ng/ml	24 Wks ng/ml
Color				
White	2.86	4.00	1.82	2.63
Red	7.20	2.91	1.39	2.48
Blue	5.19	2.03	2.02	1.27
Regimen				
2L:2D	8.05	2.95	1.82	2.01
12L:12D	2.12	3.00	1.66	2.24
Experimental Means	5.08	2.98	1.74	2.13

[1/] Androgen levels are presented and analysed by lines because the blood samples per line were drawn at two different times of the day.

Table 41 Analyses of variance for plasma androgen levels in male turkeys at 18 and 24 weeks of age. (Experiment 2)

Source of Variation	Degrees of Freedom	Mean Squares			
		LW Males		MW Males	
		18 Wks	24 Wks	18 Wks	24 Wks
Color (C)	2	37.76	7.70	0.82	4.47
Regimen (R)	1	211.44	0.02	0.15	0.31
C X R	2	46.82	25.50	0.31	0.84
Experimental Error	6	103.21	14.78	0.60	2.41
Sampling Error	12	1.27	0.22	0.21	0.14
Total	23				

could be shown in androgen levels due to the very high variation among individuals treated alike. There were no readily apparent trends in the data except if one looked at the values for those birds reared under blue diurnal (12L:12D) regimens. Blood androgen levels were compared within each line 4 times. Within each line, the color by regimen values can be looked at in six combinations. Three out of 4 times the MW toms and 2 out of 4 times the LW males on the blue 12L:12D light combination displayed the lowest androgen levels of the six possible measures. This could indicate that androgen levels may be reduced under blue 12L:12D and was consistant with the necropsy testes measures as shown in Figures 9 and 10.

Behavioral Responses

In Experiment 2, observations were made comparing the behavior of the poults immediately upon being placed in the white, red or blue pens. Birds under white light were active, with bouts of feeding, drinking and running about the pen. They were conscious of observer movements and maintained some distance between themselves and the observer. Birds under the red light responded in much the same manner as those under white light. However, the poults placed under blue lights behaved as though the lights had been turned off. The birds spread out, settled down and appeared to be sleeping. Very little movement was noticed even when the observer made a disturbance. A check 4 days later revealed no change in the red and white poult behavior. However, under blue light the poults were active with feeding, drinking, some running and normal pen movements. However, general activity level appeared lower than in red or white pens and the poults reacted less to movements or noise by the observer.

Observations were made in the 2L:2D pens at the start of a lights-on period. As soon as the lights were turned on, the poults headed immediately for the feed and water troughs. They spent the majority of the first 10 minutes in these activities.

Observation periods conducted at around 12 weeks of age showed some marked differences between the behavior of poults under white, red or blue environments. Upon the entrance of the observers into a white light pen all the birds would stand. Many birds were chirping and they often started to mill around in a circular movement. The poults watched the observer and spent the first part of the observation period on the opposite side of the pen from the observer. Within 5 minutes most of the birds had settled down to resting posture with occasional eating and drinking. Several birds would approach the observer near the end of the observation period but the majority remained at a distance of 2 to 3 feet away. Poults in red pens upon entrance by the observer, reacted much the same as those in the white pen. However, it seemed to take them longer, 7-10 minutes, to settle and resume normal activity. Once settled and accustomed to the observer they approached the observer more frequently, picking at ones shoe laces or the rings on ones fingers. By the end of 20 minutes they had comfortably settled down around the observer's feet, with other birds eating and drinking. The poults in the blue pens showed little reaction to the entrance of the observer. Some of the birds rose and began to feed, drink and move about the pen, but the majority remained settled where they were. Feeding activity and movement seemed less inhibited in the presence of the observer. Three minutes after entering the pen, poults were picking at the hands, shoes

and pant legs of the observer with no apparent fear. By the end of the period poults were crowded around the observer with several going so far as to roost upon the observer's legs. Movement or noise by the observer in the blue pens caused much less reaction by the birds than it did in the red or white light pens.

Day to day observations of the poults while working in the pens revealed much the same behavioral patterns. Birds under blue lights were easier to work with, showed little avoidance of workers and much less wing flapping and disturbance when they were weighed. When cleaning light filters or waterers, birds in blue pens invariably crowded up against the worker's legs. Birds in the red pens, while not as docile as those in the blue pens, were fairly calm. They did not show the crowding around the legs response but did not appear too disturbed by the presence of someone in the pen or the weighing procedure. On the other hand, birds reared under white light usually stayed on the opposite side of the pen from the worker. Wing flapping while hanging on the scales, crowding in the corners and flying attempts were much more common in the white light pens. The difference was such that farm workers preferred to weigh birds in the blue pens despite it being somewhat harder to read the wing bands and the scales in the blue pens.

No real differences were noted between behavior under the intermittent versus the diurnal regimens except for those under white lights. After 16 weeks of age, feather picking and deaths due to picking were reported in the white 12L:12D pens. In Experiment 2, four male deaths were attributed to feather picking and resultant cannibalism under white 12L:12D while none were reported under any other light color or regimen.

Also the majority of the reduced feather scores reported under white light (Tables 22-27) actually were from birds exposed to the diurnal white light and not to the intermittent regimens. However, this differences between regimens was only significant for females in Experiment 2 (Table 23).

Reproductive Phase

Mating Behavior

The mating behavior of the MW turkeys was observed for 5 weeks in Experiment 1 and 6 weeks in Experiment 2. Whenever a male was placed into a female pen, records were kept for each hen-tom combination on the number of times that the female assumed the "willing" posture or was "available" to the male for mating. Also recorded were the number of times a male attempted to mate (i.e. the number of times the male mounted the female), the number of successful or completed matings and the number of matings judged incomplete. Also the percentage of time the male struted while in the female pen was estimated. This last value was converted into a daily strut score of 1 (0-32%), 2 (33-66%) or 3 (66-100%).

The above data was used to calculate the following measures:

(1) Average Cumulative Number of Completed Matings per Male (CNCM)
= total number of completed matings per pen per period [1/] ÷ number of males per pen

(2) Average Cumulative Male Strut Score (Av. Male Strut Score)
= total of all daily strut scores per pen per period ÷ number of males per pen

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[1/] Period may signify 1 day, 1 week or the total mating behavior period. Unless otherwise stated the period used for calculation in tables was the total 5 or 6 week mating trial period depending upon the experiment.

(3) Female Mating Frequency per Average Male (Female Mating Frequency)

= [summation per pen of (total actual initially available matings per male per period ÷ total theoretical available matings per male per period) x 100] ÷ number of males per pen.

i.e. the percentage of females willing to mate with the average male per pen or treatment over a given period. This is indicative of the overall receptivity of the hens.

(4) Female Sex Drive Response to the Average Male (Female Sex Drive)

= [summation per pen of (total available matings per male per period - total initial[1/] available matings per male per period ÷ total available matings per male per period) x 100] ÷ number of males per pen.

i.e. the percentage of times the hens were still available or willing to mate with the average tom after the first attempt or mounting. This is indicative of the persistency of the female sexual desire.

(5) Average Male Sex Drive[2/]

= [summation per pen of (total attempted matings per male per period ÷ total available matings per male per period) x 100] ÷ number of males per pen.

[1/] Initial refers to the first time tom A attempts to mate hen X. Tom A will often mount with little or no treading or copulatory attempts. He then may leave to visit hen Z. If hen X remains willing then this constitutes another available mating.

[2/] If there were no available matings for a male per period then that male was deleted from the calculation and the number of males per pen became one less per each male deleted.

i.e. percentage of available matings attempted by the average male per pen. This value gives an indication of the males overall sexual desire irregardless of whether or not he successfully mated with the hens.

(6) Male Mating Efficiency

= [summation per pen of (total initial available matings completed per male per period ÷ total initial available matings per male per period) x 100] ÷ number of males per pen.

i.e. average percentage of first mating attempts completed by average males. This provides a measurement of the male's ability to complete a mating when it first becomes available to him. This is the most desirable trait in toms because hens often display a reduction in sex drive following an attempted mating.

Figures 11-14 exhibit the changes that occurred in female mating frequency, male mating efficiency, male sex drive and female sex drive under each reproductive light color during the mating trial period. (Experiment 1 - Figures 11 & 12, Experiment 2 - Figures 13 & 14). The methods for measuring and calculating the above traits and the normally occurring patterns were developed by Dr. A.T. Leighton over a period of years (Leighton, A.T., Jr., 1952, Smyth and Leighton, 1953, Carte and Leighton, 1969). In Figure 13C, the pattern of events for female mating frequency and male mating efficiency under white light depict closely the normal pattern of events which occur in a mating trial. Male mating efficiency improves over time as the male learns through experience to become more adept at mating. Turkey hens normally exhibit

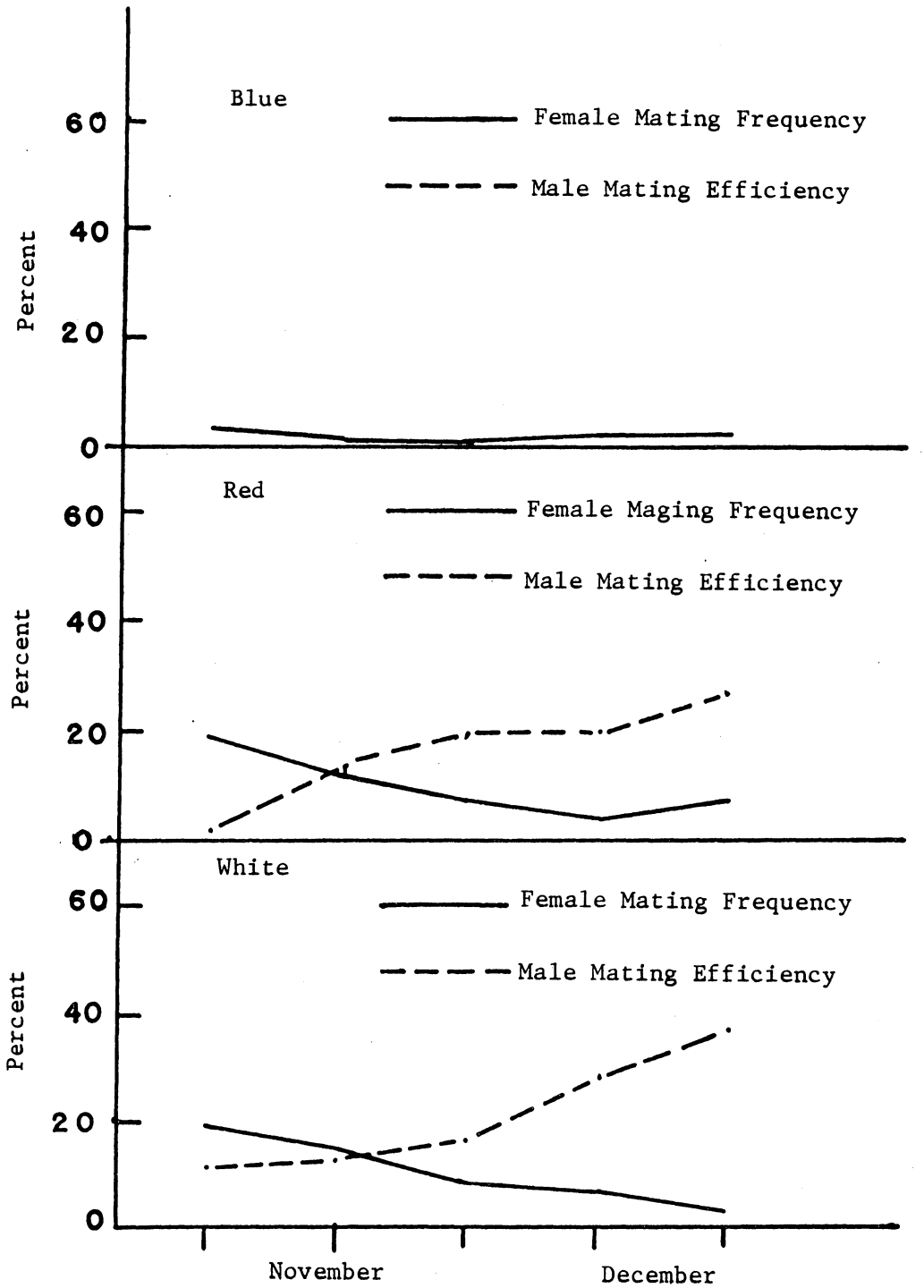

Figure 11. Mating frequency of females and mating efficiency of males in Blue, Red or White light environment by weekly intervals (Experiment 1)

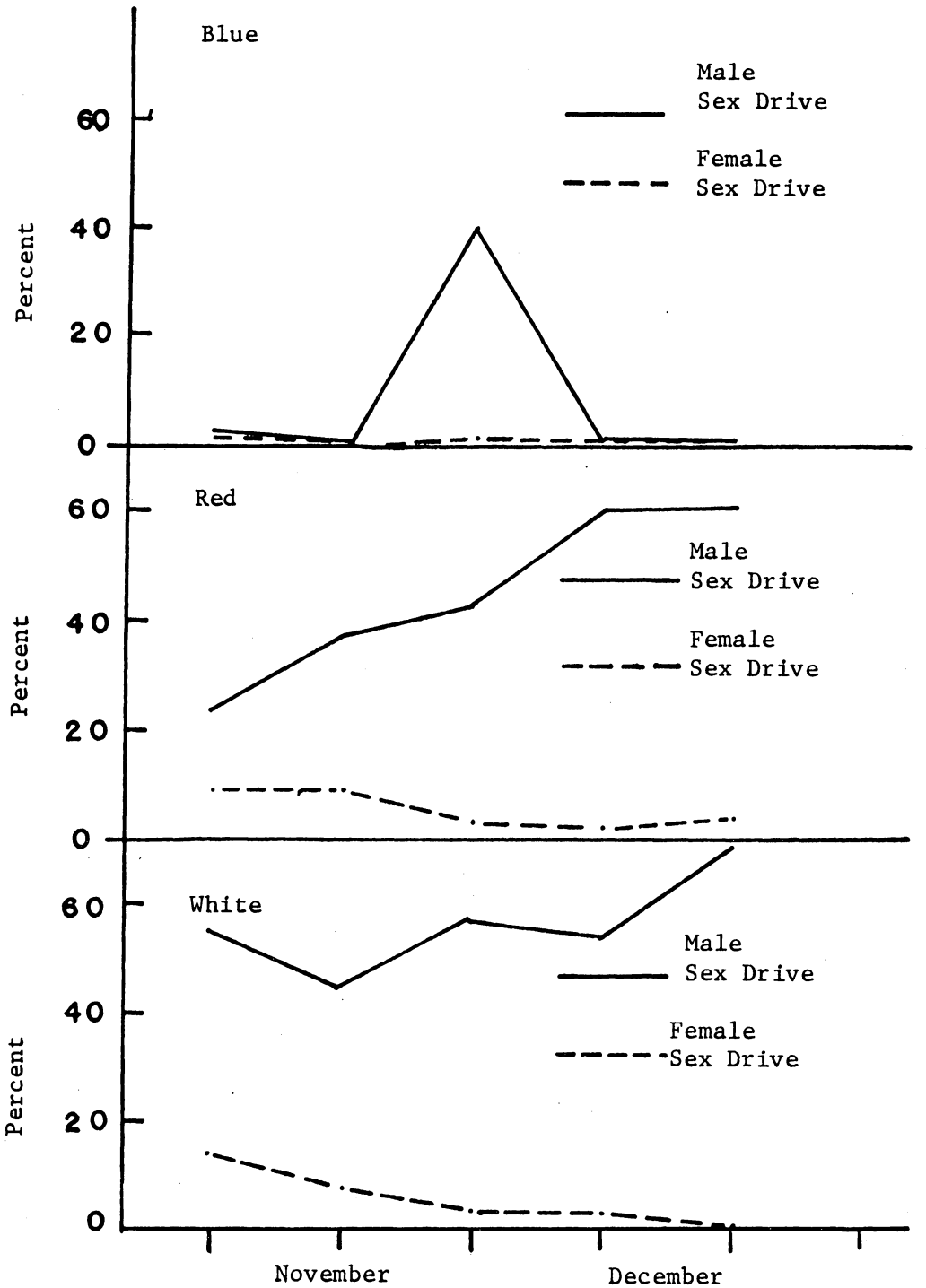

Figure 12. Sex drive for males and females in Blue, Red or White reproductive light environments by weekly intervals (Experiment 1)

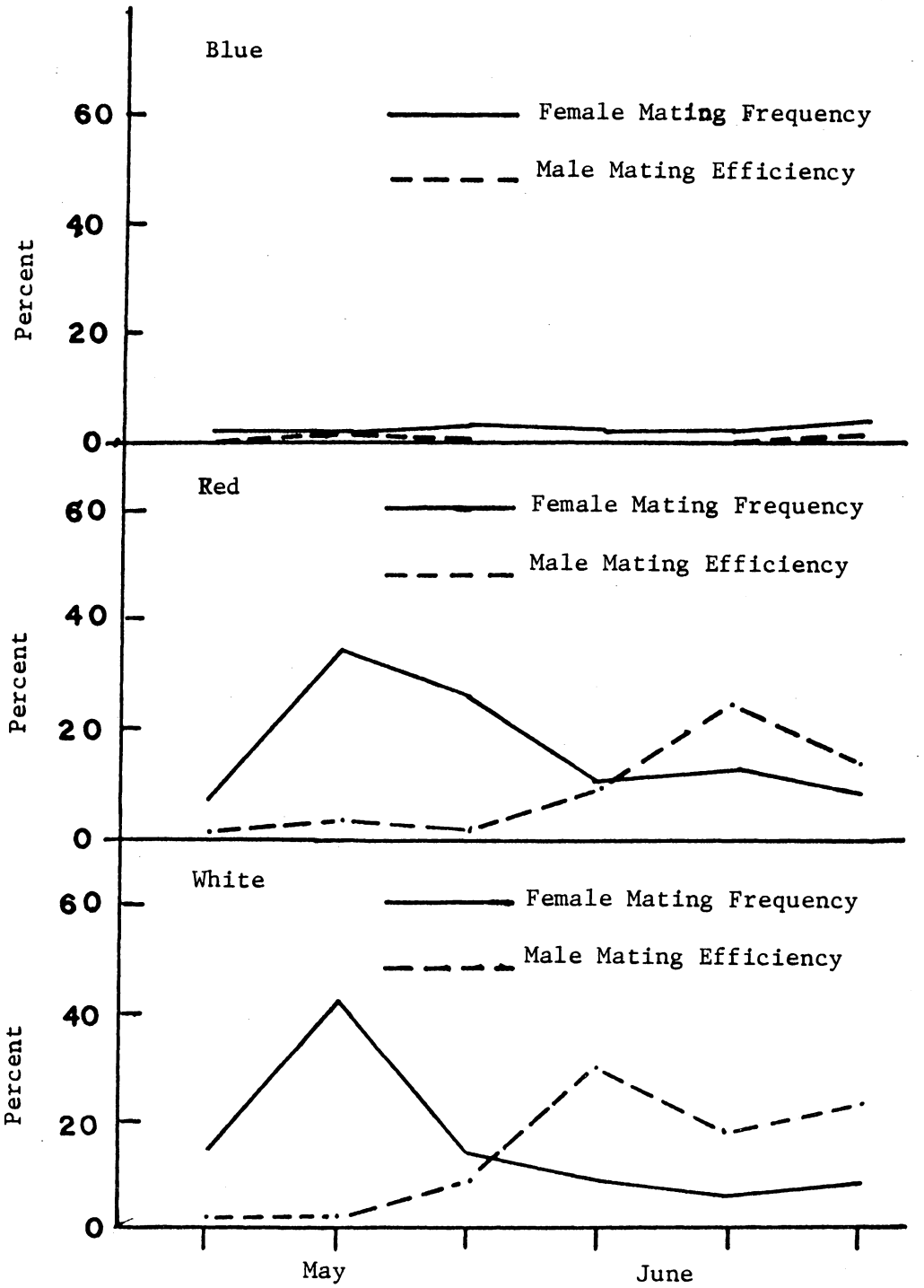

Figure 13. Mating frequency of females and mating efficiency males in Blue, Red or White light environment by weekly intervals (Experiment 2)

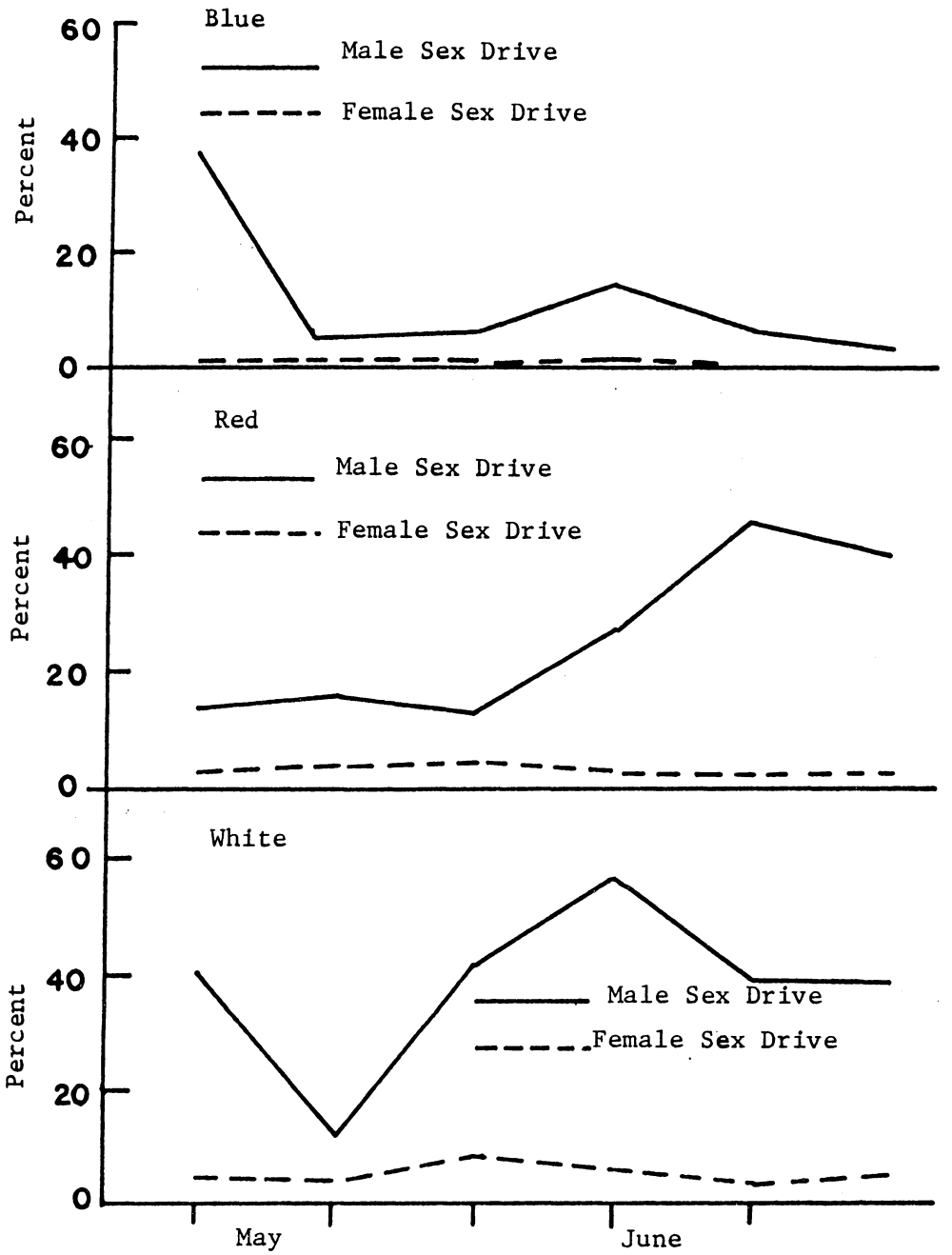

Figure 14. Sex drive for males and females in Blue, Red by White reproductive ligh environments by weekly intervals (Experiment 2)

a period of increasing sexual activity and willingness to mate during the first 2-3 weeks of the stimulatory lights program. These normally peak about the week before the onset of egg production and then decline as illustrated by the mating frequency line in Figure 13C. The normal pattern for male and female sex drive can be seen in Figure 14C. Male sex drive rises over time while female sex drive begins to decline at about the same time that mating frequency does. In work by Carte and Leighton (1969) female sex drive had considerably higher values than those reported here. The generally low values in this study, as compared to those reported by Carte and Leighton (1969), occurred fairly uniformly across all light treatment combinations. Although there were significant treatment effects, they were not large enough to account for the overall low level of female sex drive. No obvious reason can be given for the low level of response unless it was of a genetic nature or related to the totally enclosed environment system used.

There appeared to be little difference in the mating behavior traits for turkeys mated under red or white colored lights as shown in Figures 11-14 (B-C). Mating activity, however, was markedly reduced under blue light conditions (Figures 11A through 14A). Male sex drive shows occasional activity but mating efficiency was zero in Experiment 1 and only greater than zero twice in Experiment 2. Similarily, female mating frequency and sex drive were less than 4 per cent at all times under blue filtered light conditions.

In Experiment 1, female mating frequency showed a continuous decline from the start of the trial (Figure 15B) rather than a rise and fall as seen in Experiment 2 (Figure 15A). In Experiment 1, 42 out of the 48

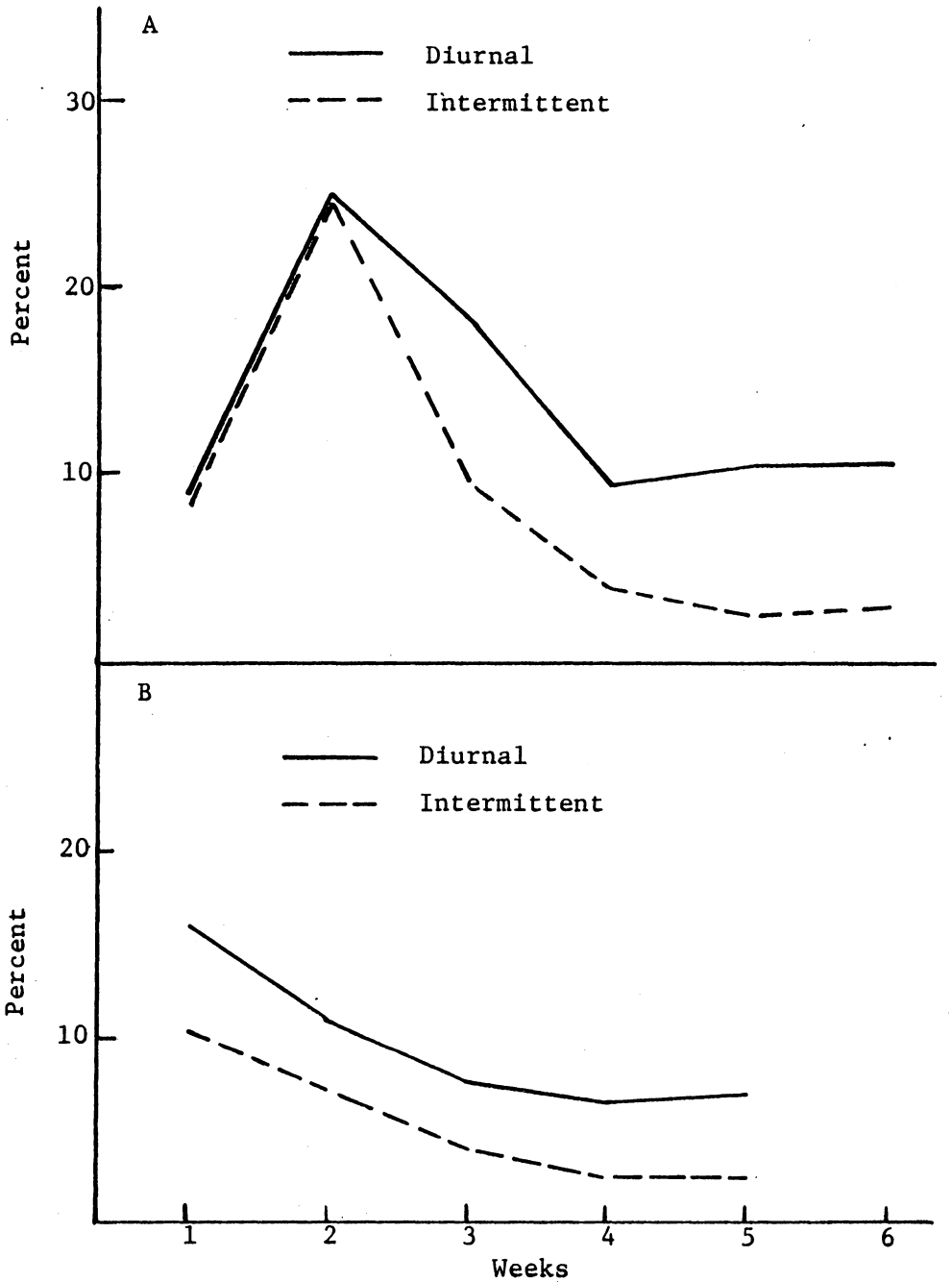

Figure 15. Mating frequency patterns of females reared under diurnal or intermittent regimen by weekly intervals. Experiment 1 (B) and Experiment 2(A)

birds from the white and red 1L:3D restrictive regimen were either about to lay or had commenced laying. This was determined by the eversion of the oviduct through abdominal pressure. This criteria is commonly used at V.P.I. and S.U. to determine production status of individual females. The number of eggs laid was recorded in the 1L:3D restricted light treatment pens. In addition, egg production data were also collected from those birds beginning on day one of the mating trial period.[1/] In Experiment 1, hens from the diurnal growth regimens had a higher mating frequency peak (16.1%) than hens from the intermittent growth regimens (10.6%) (Figure 15B). Since mating frequency declines with the onset of egg production Smyth and Leighton (1953) and Carte and Leighton (1969), the fact that the hens from intermittent red or white restricted pens were laying could account for this difference. In Experiment 2, where the birds were not laying before the start of the trial, the mating frequency of birds from both the growth regimens peaked at about the same level (25% diurnal and 24.4% intermittent) (Figure 15A).

In Experiment 1, this mating frequency peak (the highest weekly average) was recorded in the first week of the mating trials for both light regimens. Since many of the hens from the intermittent regimen were laying at the start of the trial, they probably were already on the downward side of the normal mating frequency response curve (Figure 15A vs 15B). Reasons for the diurnal regimen hens also being on the downward side of the curve are not known. It may have been a seasonal effect or because of an unknown short malfunctioning of the time clock. The latter

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[1/] Eggs were laid in week 1 (Exp. 1 - Fig. 22) but not until week 3 (Exp. 2 - Fig. 23).

is unlikely since all time clocks were inspected daily for possible malfunction.

In both experiments, the average mating frequencies per male over the entire experimental period were numerically about 40% higher for birds from the diurnal light treatments than those from the intermittent regimen. In Experiment 1, as can be seen in Figure 15B, this was merely a continuation of the lower start level caused by the advanced sexual stage of the hens as discussed above. As can be seen in Figure 15A, modifing the intermittent regimen in Experiment 2 from a 1L:3D to a 8L:18D regimen during the conditioning period, caused the females to respond initially in the same manner as those from the diurnal growth regimens. However, the mating frequency rate declined more rapidly for those reared under the intermittent regimen when compared to those reared under the diurnal light program. Thus, the overall diurnal average was still about 40% higher than the intermittent regimen, as it had been in Experiment 1.

The average mating behavior responses per male over the entire mating behavior testing period are presented in Tables 42 and 44, by growth phase light color, growth phase light regimen, and the reproductive phase light color.

The statistical analyses are presented in Tables 43 and 45. There were no significant interactions in the cumulative number of completed matings, male strut scores, mating frequencies, female sex drive or male mating efficiency when the ClxHRxC2 interaction was the error term. Therefore, the 1st and 2nd order interactions were pooled. A significant HRxC2 interaction prevented the use of a pooled analysis for male sex

Table 42 Mean cumulative number of completed matings (CNCM), male strut scores, female mating frequency, female sex drive, male sex drive and male mating efficiency on a per male basis by light color and regimen during the growth phase and light color during the reproductive phase. (Experiment 1).

Treatment	Av. CNCM[1/] per male	Av. Male Strut Score[1/]	Av. Female Mating Frequency[1/] per Male	Av. Female Sex Drive[1/]	Av. Male Sex Drive[2/]	Av. Male Mating Efficiency[2/]
Growth Phase Color						
White	2.9[a]	40.9[a]	7.5[a]	4.7[a]	40.0 (60.3)	14.3 (23.8)
Red	1.9[a]	49.9[a]	4.5[a]	9.1[a]	28.6 (42.9)	6.6 (9.8)
Blue	0.8[a]	54.6[a]	10.5[a]	7.3[a]	23.5 (29.3)	2.4 (3.1)
Growth Phase Regimen						
Intermittent	0.9[a]	42.6[a]	5.4[a]	4.3[a]	21.9 (28.6)	5.2 (7.3)
Diurnal	2.9[a]	50.6[a]	9.6[a]	9.7[a]	37.3 (54.4)	9.6 (14.4)
Reproductive Phase Color						
White	2.8[a]	55.2[a]	11.0[a]	11.6[a]	52.3 (52.3)	13.6 (13.6)
Red	2.9[a]	53.7[a]	9.9[a]	7.7[a]	31.1 (31.1)	8.2 (8.2)
Blue	0.0[a]	30.9[b]	1.6[b]	1.6[a]	3.8 ----	0.0 ----
Experimental Mean	1.9	46.6	7.5	7.0	30.5 (42.7)	7.7 (11.2)

1/ Means within each treatment with different superscripts are significantly different ($P \leq 0.05$).

2/ Values within parentheses are averages from the pens under red and white reproductive lights. Male sex drive and mating efficiency were not analysed due to missing data which could not be effectively estimated by missing cell techniques.

Table 43 Analyses of variance for cumulative number of completed matings (CNCM), male strut scores, female mating frequency, and female sex drive values across all reproductive pen colors. (Experiment 1).

Source of Variation	Degrees of Freedom	All Reproductive Pens			
		Av. CNCM per male	Male Strut Score	Mating Frequency 1/	Female Sex Drive 2/
Growth Color (C1)	2	7.1	314.4	65.3	5.3
Growth Regimen (R)	1	16.7	285.3	140.0	156.3
Reproductive Color (C2)	2	16.1	1107.6**	288.2*	287.6
Error (Pooled Interactions)	12	6.6	99.3	61.1	105.7

1/ Analyses conducted on weighted arcsin transformation value ($1X10^{-3}$)

2/ Analyses conducted on unweighted arcsin transformation values.

* $P \leq 0.05$.

** $P \leq 0.01$.

Table 44 Means of the cumulative number of completed matings, male strut scores, female mating frequency, female sex drive, male sex drive and male mating efficiency on a per male base by light color and regimen during the growth phase and by light color during the reproductive phase. (Experiment 2)

Treatment	Av. CNCM[1] per male	Av. Male Strut Score[1]	Av. Female Mating Frequency[1] per Male	Av. Female Sex Drive[1]	Av. Male Sex Drive[1]	Av. Male Mating Efficiency[2]
Growth Phase Color						
White	1.9^{a}	70.6^{a}	14.5^{a}	4.8^{a}	28.4 (37.4^{a})	8.1 (11.6^{a})
Red	2.7^{a}	58.2^{a}	7.7^{a}	5.5^{a}	25.8 (32.2^{a})	8.5 (10.6^{a})
Blue	0.7^{a}	65.2^{a}	12.6^{a}	3.3^{a}	10.5 (10.5^{b})	1.9 (1.9^{a})
Growth Phase Regimen						
Intermittent	0.7^{a}	60.2^{a}	8.6^{a}	3.7^{a}	14.6 (19.5^{a})	3.4 (4.6^{a})
Diurnal	2.9^{a}	69.2^{a}	14.6^{a}	5.3^{a}	32.0 (33.9^{b})	10.1 (11.5^{a})
Reproduction Phase Color						
White	3.7^{a}	70.2^{a}	15.8^{a}	6.9^{a}	32.1 (32.1^{a})	11.3 (11.3^{a})
Red	1.4^{a}	77.2^{b}	16.4^{b}	5.7^{b}	21.2 (21.3^{a})	4.8 (4.8^{a})
Blue	0.2^{a}	46.6^{b}	2.6^{b}	0.9^{b}	6.9 ----	0.7 ----
Experimental Mean	1.8	64.7	11.6	4.5	22.7 (26.7)	6.6 (8.0)

[1] Means within each treatment with different superscripts are significantly different. ($P \leq 0.05$)

[2] Values within parentheses are averages from the pens under red and white reproductive lights. Missing data from several reproductive blue light pens presented analysis on data including these blue pens. However, sufficient data was present to allow analysis if the blue pens were deleted.

Table 45 Analysis of variance for cumulative number of completed matings, male strut scores, female mating frequency, and female sex drive analysed across all pens and for male sex drive and male mating efficiency values analysed for red and white pens. (Experiment 2)

		Mean Squares							
		All Reproductive Pens				White and Red Reproductive Pens			
Source of Variation	df	CNCM	Male Strut Score	Mating Frequency[1/]	Female Sex Drive[2/]	df	Male Mating Efficiency[1/]	Source of Variation	df	Male Sex Drive
Growth Color (C1)	2	6.5	233.5	82.2	17.7	2	178.3	C1	2	491.8*
Growth Regimen (R)	1	22.2	364.5	158.4	34.7	1	78.6	R	1	311.3*
Reproductive Color (C2)	2	19.5	1537.5**	644.4**	285.8**	1	106.3	C2	1	177.6
Error (Pooled Interaction)	12	8.6	196.5	78.8	18.9	7	77.1			
								C1 X R	2	49.9
								C1 X C2	2	71.0
								R X C2	1	417.6*
								Error (C1 X R X C2)	2	16.7
Total	17					11			11	

[1/] Analysis conducted on weighted arcsin transformation (1×10^{-3})

[2/] Analysis conducted on arcsin transformation

* $P \leq 0.05$

** $P \leq 0.01$

drive in Experiment 2.

The average cumulative number of completed matings (CNCM) were fairly low in both experiments. Even with a pooled error term, no significant differences ($P \leq 0.05$) were detectable in CNCM's for either experiment.

However, three very strong numerical patterns were evident in both experiments and, while not statistically significant, they warrant consideration. First, in both experiments, the average cumulative number of completed matings per male (CNCM) were markedly reduced under blue lights. These were 0.0 and 0.16 CNCM per male for Experiment 1 and 2 respectively. The 0.16 CNCM was due to an exceptional situation where 3 matings occurred between the same male and female. Therefore, although completed matings will occur under blue light, they are very rare. Secondly, the average CNCM's for birds reared under diurnal light were 3 to 4 times higher than those reared under an intermittent regimen. This would appear to be due to a combination of higher female mating frequency (i.e. more available matings), higher male sex drive and higher male mating efficiency. Thirdly, birds reared under red or white light also had an average CNCM 3 to 4 times higher than those reared under blue light. This was largely determined by improved mating efficiency and male sex drive under the stimulatory influence of the longer wavelengths of light.

Strutting scores were significantly ($P \leq 0.05$) higher for males mating under the red or white reproductive light than those mating under blue lights in both Experiment 1 and 2. The light colors and light regimens during the growth period had no significant effect on strut scores.

The average female mating frequency response per male was 6 times

higher under red or white reproductive lights than under blue light. This difference was significant in both experiments. Rearing hens under either the red light color or the intermittent light regimen appeared to reduce the number of females willing to mate in both experiments but significant differences could not be detected for either factor.

There was a marked trend towards a lower female sex drive for hens in the blue reproductive light environment in Experiment 1. This effect was significant in Experiment 2. The apparent reduced female sex drive for hens reared under intermittent light regimen was not significant.

As indicated in Tables 42 through 44, no data was obtained for male sex drive or mating efficiency for several red and blue pens in Experiments 1 and 2. Male sex drive and male mating efficiency values were calculated only for those males with whom females assumed the "willing" sexual crouch. When females were never willing to mate with a tom, there was no way to estimate the number of matings the tom would attempt or complete. There seems to be some yet unknown characteristics which provide certain toms with a greater "sex appeal" to hens. In the course of conducting mating trials, one would find certain toms for whom most of the females in a pen would assume the sexual crouch. In Experiment 1, pen 501 provided a good example. The females in this pen were never willing to mate with Tom K6306, were only willing infrequently with Tom K6287, but showed a great deal of interest in mating with Tom K6743. While failure to strut by the tom may lead to this response, females would also ignore males which appeared to strut as well as any other tom. This reaction is referred to as preferential mating (Carte and Leighton, 1969).

A second factor tending to eliminate males from the analyses because

of the absence of willing females, was the decline in mating frequency and sex drive in females as they came into egg production. Normally, when turkey hens are removed from a restricted light regimen and placed under stimulatory light regimen of 16L:8D, there is a 2 to 3 week period during which sexual activity is high, peaks out and then declines as the hens begin to lay. Because some of the hens from the intermittent light treatment during the growth phase were laying at the start of Experiment 1, this period of high female willingness was lacking in several of the pens. Forty-two out of forty-eight hens reared under white and red intermittent growth phase regimens were ready to, or were laying, at the start of the mating trials. For these same pens, the mating frequency averaged only 2.3% compared to 8.5% in Experiment 2 where none of the females were laying at the start of mating trials.

The third factor leading to males with no matings available to them was the blue light color. Mating activity was generally low in blue light pens as seen by Tables 42 and 44. Sexual activity of any type was not seen in 4 out of the 12 blue pens in Experiments 1 and 2.

Male sex drive and male mating efficiency values are presented in Tables 42 and 44. The values within the parenthesis are averages for pens under red and white reproductive light only. In experiment 1, one red and one blue reproductive pen had no available matings for any males. This left those pens with no male sex drive and male mating efficiency values. Therefore, that data from Experiment 1 was not statistically analysed. However, these measures appeared lower under blue reproductive lights. There was also a trend to lower values for birds from the intermittent light and the blue growth light environment.

In Experiment 2 (Table 44) toms reared under red or white light had significantly)P $\leq$ 0.05) higher sex drive than those reared under blue light. Toms reared under diurnal light showed a significantly (P $\leq$ 0.05) higher sex drive than those reared under the intermittent light. Toms from the intermittent growth regimens did better under red reproductive lights than under white, while those from the diurnal growth regimens showed a higher sex drive under the white reproductive light. This gave rise to a significant (P $\leq$ 0.05) regimen by reproductive color interaction. The high male sex drive value for toms from the diurnal growth-white reproductive light combination also accounts for most of the significant differences between the diurnal and intermittent growth phase regimens.

Most mating behavior characteristics were inhibited when turkeys were placed in blue light pens. Strut score and mating frequency were statistically lowered in both experiments. Female sex drive was significantly lower under blue light in Experiment 2. Although not significant, zero and near zero CNCM values were recorded in the blue light pens in Experiment 1 and 2, respectively. The lack of sexual activity in a number of the blue light pens prevented the determination of values and subsequently the statistical analysis of male sex drive and male mating efficiency across all pens in both experiments.

In both experiments, all the mating behavior traits measured were consistantly higher, numerically, for turkeys reared under the diurnal growth regimen than for those reared under intermittent regimen. This is readily apparent in Figures 16-19. Figures 16 and 17 show bar graphs of the male mating efficiency, female mating frequency, female sex drive and male sex drive averages over the mating trial period by growth light color

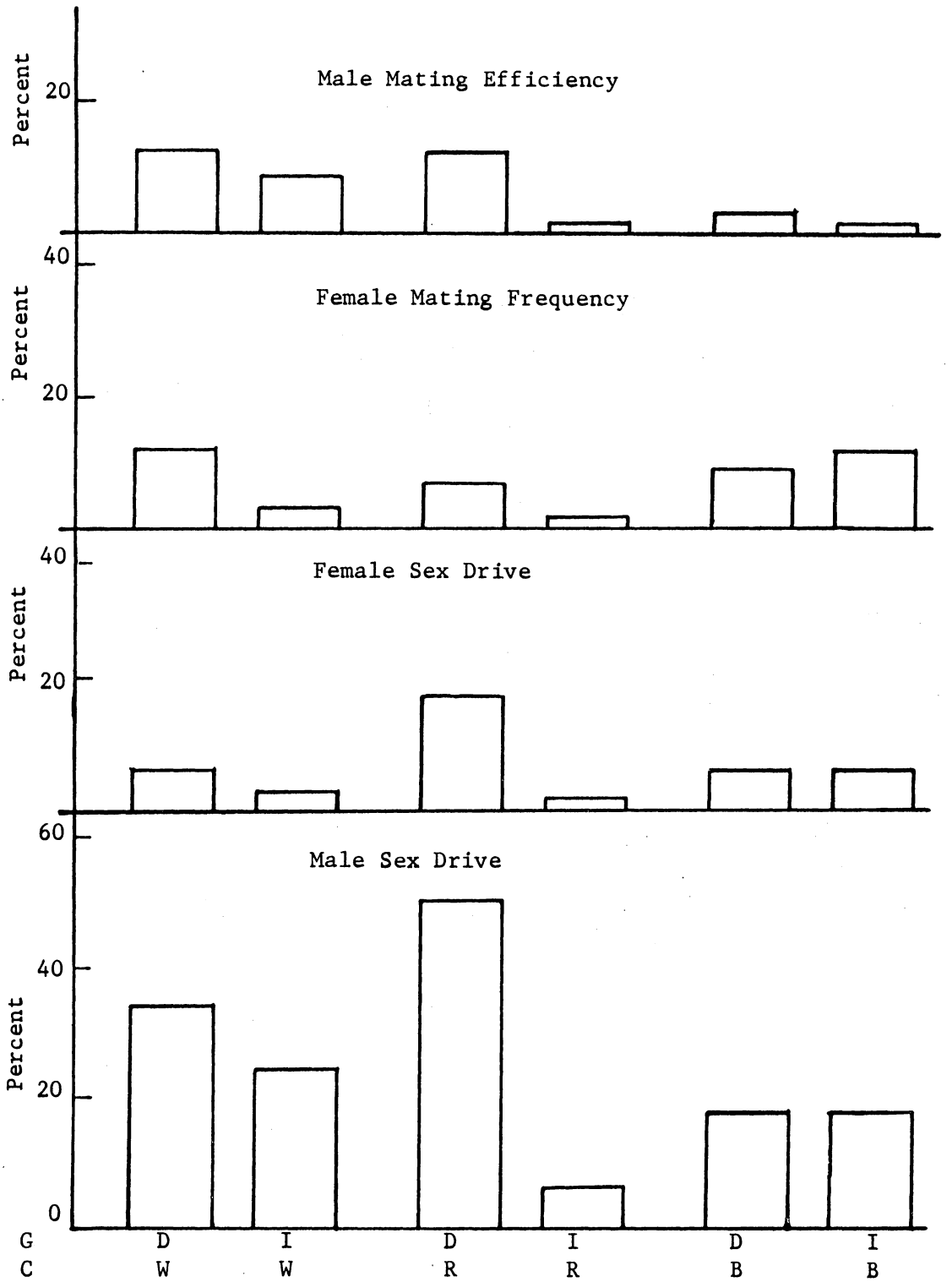

Figure 16. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth regimen (G) and growth phase (C) light color. D= diurnal, I= intermittent, W= white, R= red, B=blue (Experiment 1)

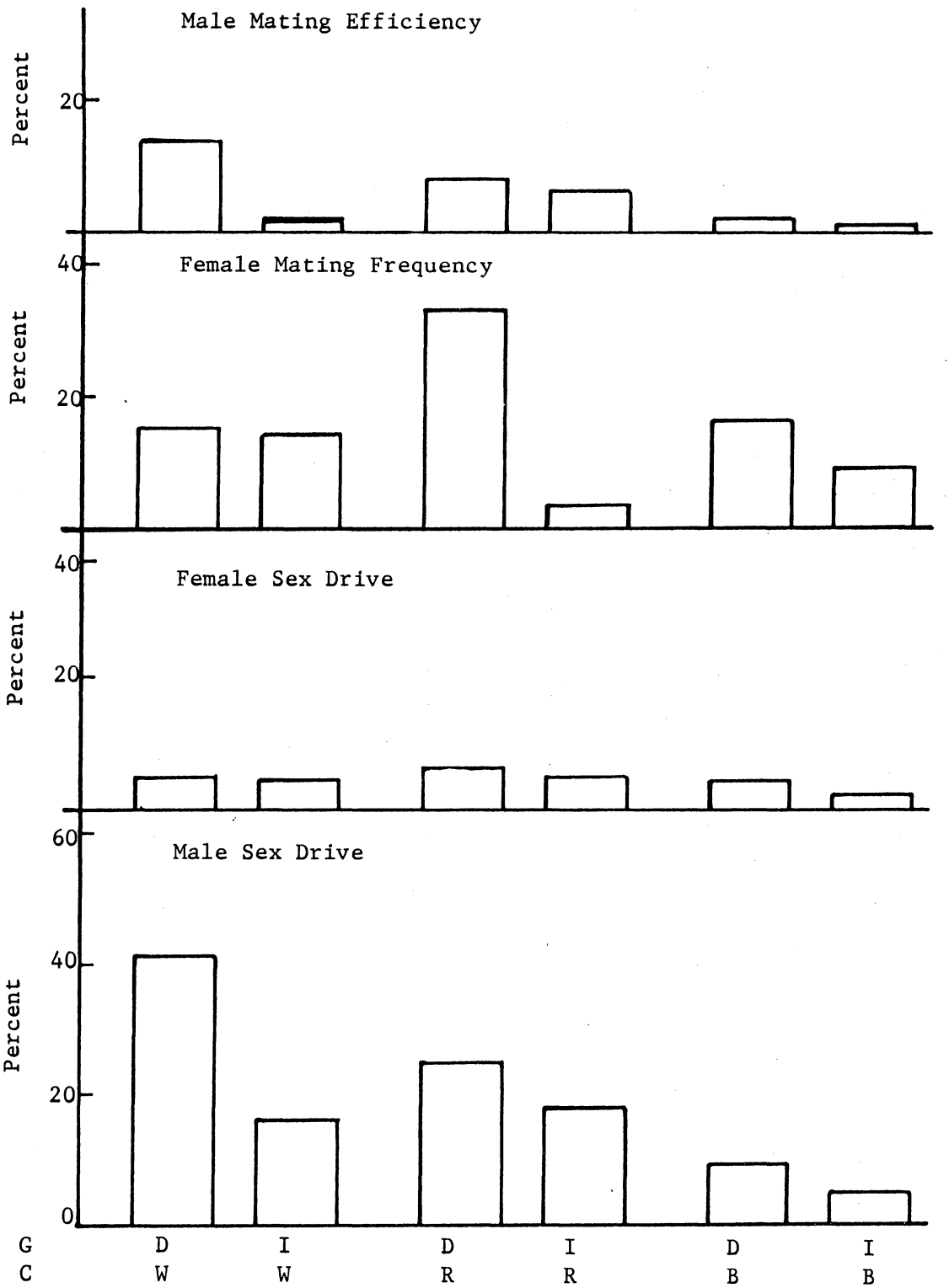

Figure 17. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth regimen (G) and growth phase (C) light color. D= diurnal, I=intermittent, W=white, R=red, B=blue (Experiment 2)

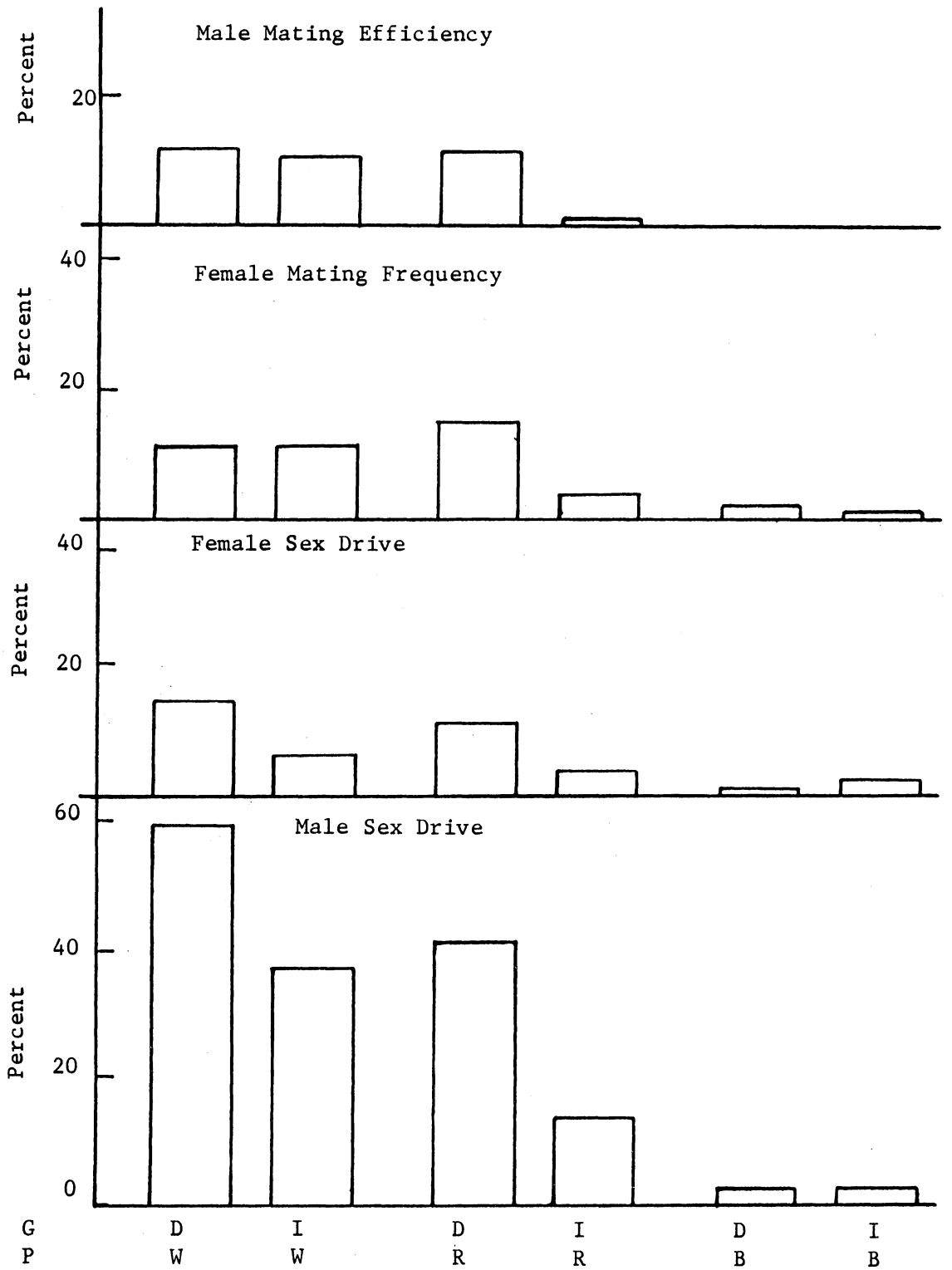

Figure 18. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth regimen (G) and reproductive phase (P) light color. D= diurnal, I= intermittent, W= white, R= red, B= blue (Experiment 1)

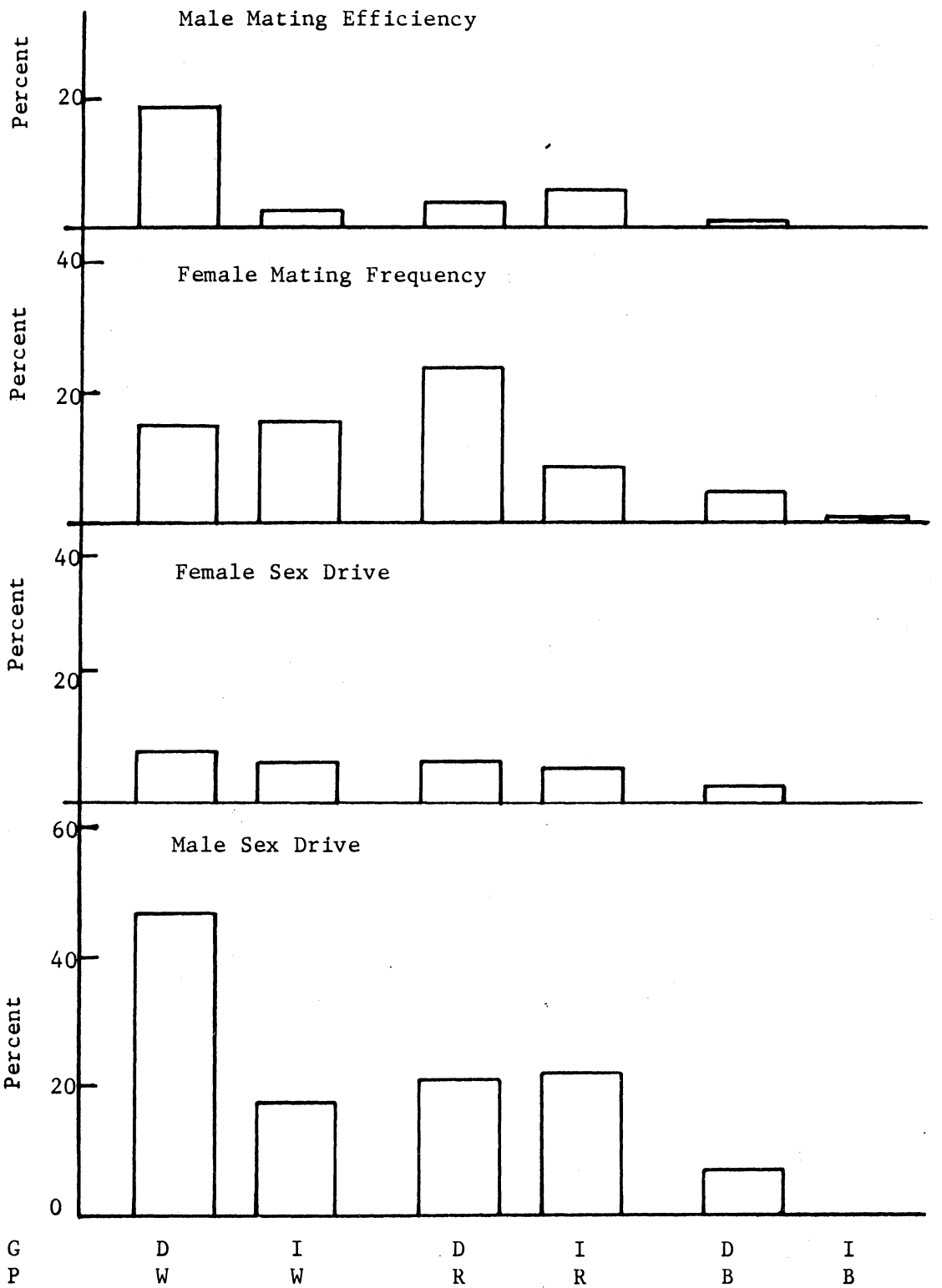

Figure 19. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth regimen (G) and reproductive phase (P) light color. D= diurnal, I= intermittent, W= white, R= red, B=blue (Experiment 2)

and regimen. In Experiment 1, mating activity for birds from the white or red diurnal pens were consistantly higher than those from the intermittent pens. Again this may be due to many of these hens being in egg production at the time of lay. In Experiment 2, this trend was not apparent for the females except for those reared under red light. However, the trend did continue for the males. It was also more noticeable for those birds reared under blue light.

In general the male mating behavior measures for birds reared under blue light were usually lower than those from toms reared under red or white light. This was found in both experiments (Figures 16 and 17).

Figures 18 and 19 show the mating behavior traits measured over the whole mating trial period by reproductive light color and growth phase regimen. The lack of activity under blue lights was the most noticeable feature. Male mating efficiency and male sex drive appeared to be lowered for toms from the intermittent growth regimens regardless of reproductive color except for red 2L:2D in Experiment 2. The trend to lower responses from hens reared under intermittent light was apparent for female mating frequency and female sex drive except for the mating frequency values from females placed under white light in both experiments.

Bar graphs are presented in Figures 20 and 21 showing male sex drive, female sex drive, mating frequency and male mating efficiency for Experiment 1 and 2 by growth phase-reproductive phase light color combinations. Male sex drive followed the same pattern in Experiment 1 and 2. Under stimulatory white light, sex drive was highest for birds reared in white light and lowest for toms reared under blue. When placed under red light during the reproductive phase, toms from red growth pens consistantly

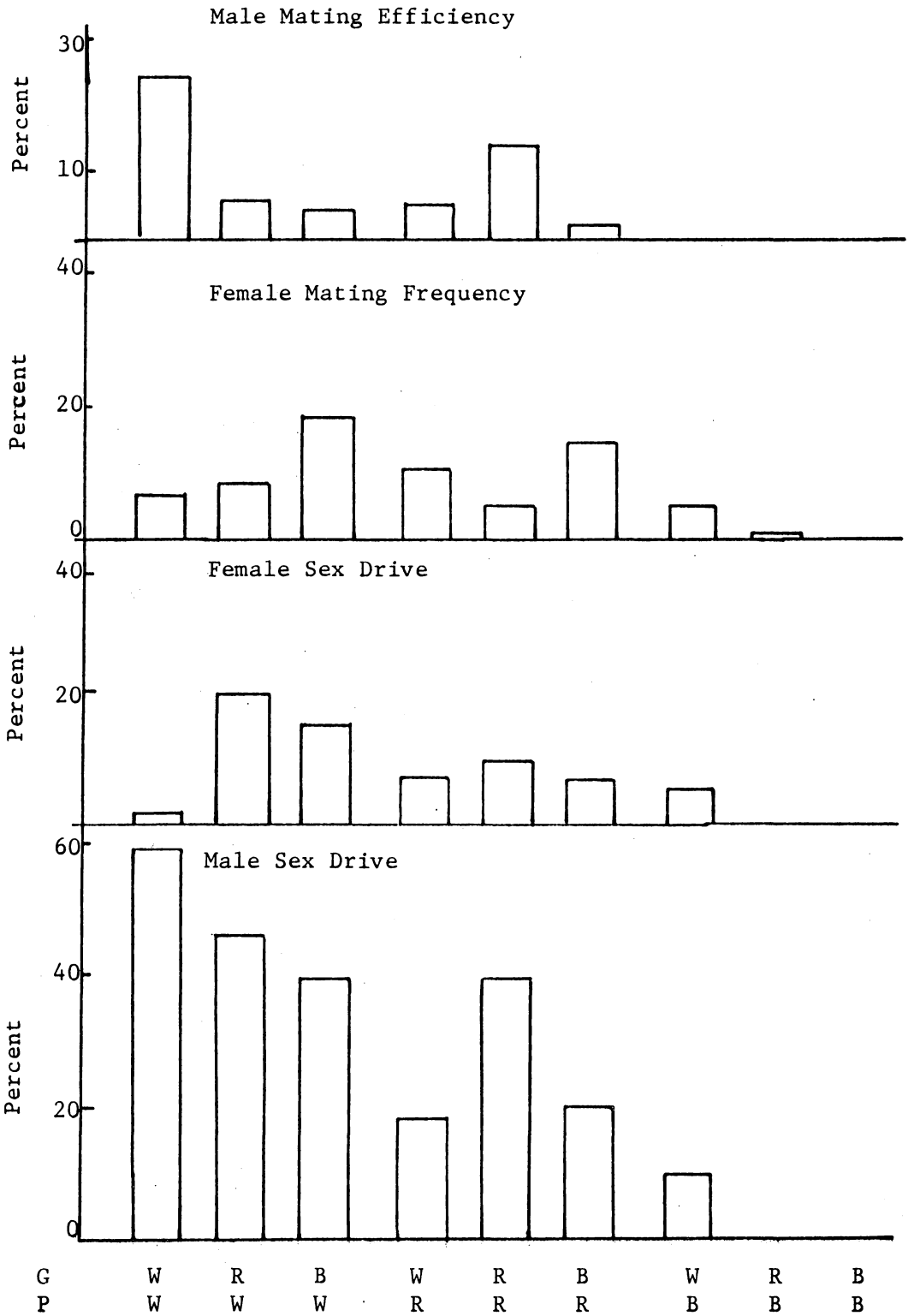

Figure 20. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth phase (G) and reproductive phase (P) light color. W= white, R= red, B= blue (Experiment 1)

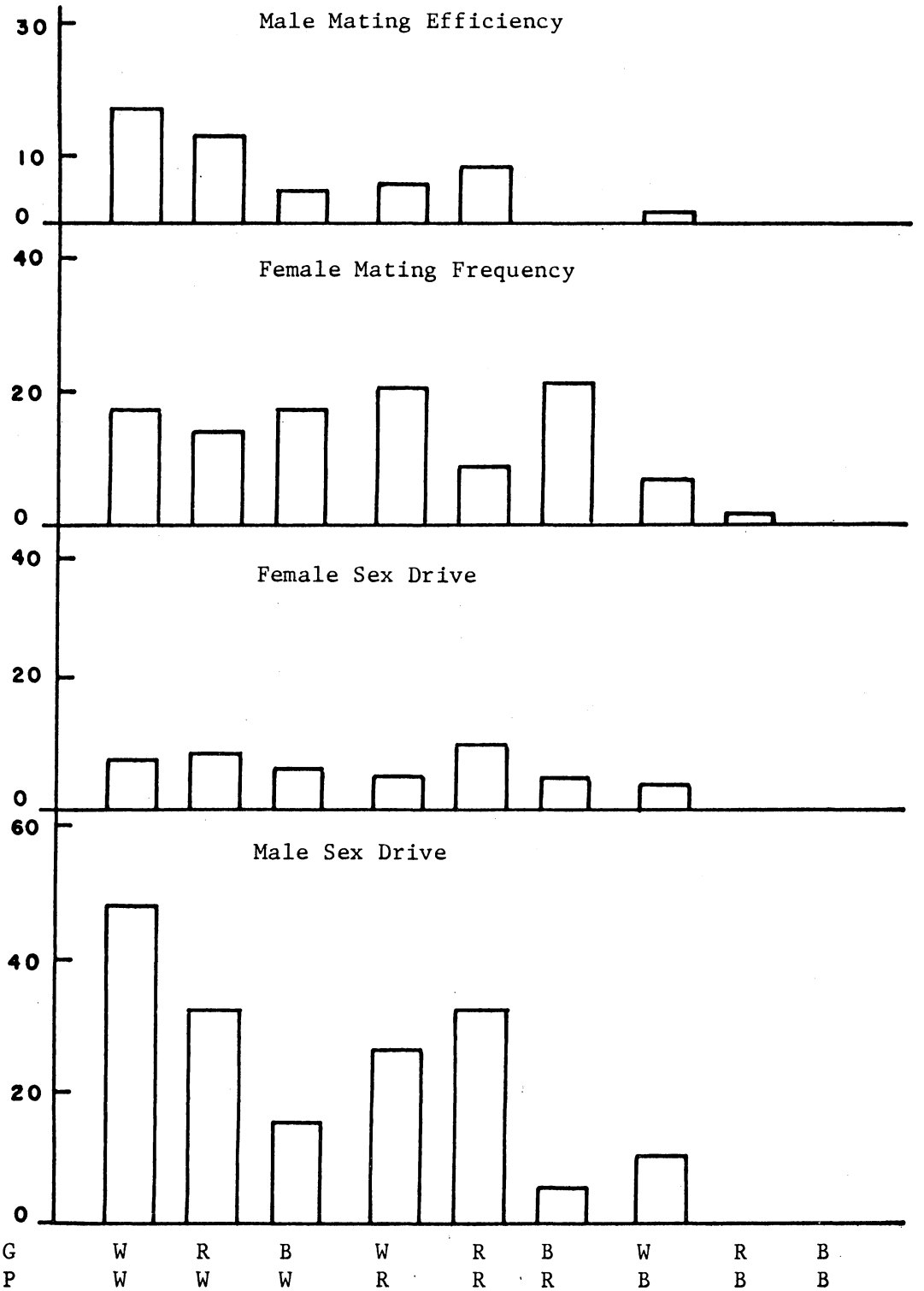

Figure 21. Mean male and female sex drive, female mating frequency, and male mating efficiency values over the whole mating trial period plotted by growth phase (G) and reproductive phase (P) light color. W= white, R= red, B= blue (Experiment 2)

displayed a higher sex drive. Toms exposed to white or blue light during the growth phase and subsequently exposed to red light during the reproductive phase showed no differences in male sex drive in Experiment 1 but those from blue pens were markedly reduced in Experiment 2. Of all the males placed in the blue reproductive light pens, only those reared in white light environments showed any measurable sexual activity.

Hens exposed to red and blue light during the growth period and subsequently placed under white lights during the breeding season exhibited about twice the female sex drive of the other combinations in Experiment 1 but not in Experiment 2 (Figures 20 and 21). Those hens reared under white light and then placed in white light during the reproductive phase showed very low sex drive in Experiment 1 and 2. Again as with the males, only hens reared under white light showed any sexual activity in a blue reproductive light environment.

In Experiment 1, female mating frequency was highest when birds were moved from the blue growth pens to the white or red light pens during the reproductive phase (Figure 20). Again this was largely due to the fact that many of the hens from the red and white intermittent growth pens were past their peak period of sexual activity (See Figure 15B) and were laying eggs at time of transfer to their reproductive light environment. Again note the low level of sexual activity for hens placed into blue reproductive light pens. However, some hens reared in white growth pens and a few females reared under the red lights were willing to mate under blue lights in both experiments.

Male mating efficiency was consistantly higher for toms from the white-white light combination, followed by the red-red combinations.

There was little difference among the remaining combinations, except for those in blue reproductive pens. There were no completed matings in any blue reproductive pen in Experiment 1 and 1 male from a white rearing environment completed 3 matings in a blue pen in Experiment 2.

Several general patterns are illustrated by these graphs (Figures 16 through 21). Toms and hens mated under white light showed the best average all round mating activity. This was especially noticeable for males reared under white light. Mating activity was reduced consistantly for birds reared under intermittent light regardless of growth or reproduction color to which they were exposed. Birds mated under blue light showed very limited mating activity. Hens reared and mated under blue showed virtually no sexual desire. A willing hen was seen only once in all the blue-blue pen observations.

General Behavior During Mating Behavior Study

During the recording of specific events occurring within each pen during the mating behavior trials, notes were also made on any unusual behavior which occurred. Two observers also subjectively compared general activity patterns and the general degree of nervousness exhibited by the turkeys.

Turkeys in a commercial flock generally exhibit relatively little fear of the person working in the flock. Turkeys at the V.P.I. and S.U. Research Center usually maintain a much greater distance between themselves and observers. This probably relates to the fact that they are handled more frequently for weighing, artificial insemination and other experimental procedures. Therefore, any factor that has a tranquilizing effect, such as blue light, or which increases flightiness, is readily apparent by

its effect on this distance and the ease of handling the turkeys.

In mating behavior trials conducted previous to these studies, a general behavioral pattern was noted. At the start of the studies turkeys were usually nervous and flighty. Ordinarily within 2-3 days they settled into the routine of the males moving into the female pens and the movement of the observers. The moving of males then usually occurred fairly quietly. When the males were in the female pens, the females usually either assumed a sexual crouch or went about the pen eating, drinking, dusting, and exploring nests in a normal manner. The majority of the males will strut and attempt to mate the willing females. Toms normally are willing to enter and remain in the female pen. Occasionally a male has no interest in the females and merely walks about the pen or stays close to the door trying to get out. Once accustomed to the mating trial routine the turkeys pay little attention to the observers.

General Behavior

As described above, the hens normally either assumed a sexual crouch or ignored the male during mating trials. However, in these trials not all pens reacted in the accustomed manner.

While a number of the toms in the blue lighted pens showed some sexual activity by strutting among the females, very few females assumed the sexual crouch (i.e. were "willing" to mate). However the females did not exhibit the normal non-mating responses either. Females in many of the blue pens would stand in a group in one part of the pen and very seldom move. Eating, drinking, dusting were done to a very limited degree. Any bird movement about the blue pens was very slow compared to that observed in white or red pens. It was almost like watching a slow-

motion movie. The only reaction exhibited by these birds to the movements of an observer was to slowly swing their heads in the direction of the movement. Much the same huddling and slow-motion like behavioral patterns occurred in all blue lighted reproduction pens, irregardless of the light treatment during the growth phase.

Turkeys in red lighted pens were more active than those in blue, and slightly less active than those exposed to white light. The females congregated in the half of the pen farthest from the observer for longer periods of time than did those hens in the white pens. This limited their range of movement. Hens exposed to red light became startled as easily as hens exposed to white light. Turkeys under white lights generally appeared more natural in movements than those in the red pens. They moved about faster, were more restless and ate and drank more often. However, these differences were quite subtle when compared to the marked difference in behavior between the birds in the blue lighted pens versus those in red and white pens. Neither the light color nor regimen during the growth phase appeared to have any distinguishable effect on the general activity of the birds within the white, red, or blue reproductive pens.

Nervousness (Excitability)

As with the growth phase, the easiest birds to work with were those under the blue lights. The toms could be easily moved in and out of the female pens. The females were easily approached and caught for insemination. During experimental or routine procedures they were much less likely to fly around or crowd into the far corner of the pen than birds in the red or white pens. Within the blue lighted pens, there was no

obvious pattern as to which growth phase light conditions led to the more placid birds.

The birds under red light during the reproduction period were more excitable than those under blue but more tranquil than those under white lights. Within the red lighted pens, males and females reared under red light were the most excitable group both while moving the toms and when observing the mating trials. Neither white nor blue colored light nor light regimen during the growth phase had any noticable effect on the excitability of the birds in the red lighted reproductive pen.

In the white lighted pens, the most placid birds were those reared under red light. Turkeys reared under blue lights were the most difficult to move and the most nervous when an observer was in the pen.

Aggressive Behavior

Aggression can be expressed in several directions among turkeys in mating trials. Agonistic behavior may occur between the toms, the hens, the toms and the hens or between Meleagris gallopavo and Homo sapiens. Male-male fights are fairly common and to be expected, especially in the first week of trials when the males are adjusting to the new pens and each other. Females rarely fight with each other very seriously but seem to establish their dominance relationship by mild pecking. Male-female fights were very rare in previous studies, especially in the early portion of the mating trials when most of the females were mainly interested in sex. Aggressiveness of toms towards human observers or workers does occur but more often in all male growth pens than when males are in the mating trial pens.

Toms in the white lighted reproductive pens would often fight amongst

themselves during the first week or two of the trials. Female-female relationships were normal under all light colors and of no consequence in these behavior studies. In the white light environment, neither fighting between males and females nor attacks on observers by toms were observed during the mating trials.

Three types of aggressive behavior, tom-tom, tom-hen, and tom-human, were noted among the turkeys under blue reproductive light. Only the males which had been reared under white light showed a noticeable amount of fighting amongst themselves. This usually ended by the end of the 2nd week of mating trials.

Fighting between toms and hens reared under the red diurnal and red intermittent regimens would occur while the male was in the female pen during mating trials. These fights occurred more often in Experiment 1 than Experiment 2. In addition, fighting between hens and toms reared under blue light and maintained under blue light occurred at a high level in both Experiments 1 and 2. While this fighting was more prevalent during the first two weeks, some male-female fights continued to occur until the end of the mating trials.

In Experiment 2, several toms would rush at (i.e. attack) the observers when they first entered the pens each day. However, this attack was mostly bluff. It would usually cease if you quietly pushed the toms away and carried on with the trial. The toms seldom "attacked" again during that period. This type of attack seemed to be mainly bluff and because it only occurred in the blue light pens it was called the "Blue Bluff Type". The majority of the "Blue Bluff Type" attacks occurred in pens with toms reared under red light. A few attacks did occur in one

pen of toms reared under blue light.

In the red light breeder pens, toms reared under red or white light showed little tendency to fight amongst themselves. They spent a great deal of time strutting both in the male pen as well as in the pen with the hens. Male and female fighting occurred in only one of the above pens and it usually involved the same hen. This hen was reared under red light. However, fights were common in red lighted pens between toms and hens reared under blue light.

The behavior of the toms reared under blue lights and placed in red breeder pens was the most dramatic of all. This was especially true for those reared under the blue diurnal (Blue 12L:12D) regimens. First, almost all of the males appeared to strut continuously, whether they were with the females or in their own pen. This strutting was noticed whenever anyone looked in the pen whether during mating trials or not. Secondly, the first 2-3 weeks of mating trials, the males often behaved strangely when in the female pens. They would strut, approach a willing hen, then sometimes half-attack her or else fly over her, seemingly total disoriented. Often the male would fly over the female, not stopping until he hit the wall or wire partition. Thirdly, many of the males, especially those reared under the 12L:12D regimen, were super-aggressive towards the observers in the pens. The first 2 weeks these males would regularily attack the observer standing in the tom pen. These attacks were quite violent with the toms flying at the observer and raking at them with his feet and spurs much in the manner of a fighting cock. These males literally chased one of our more inexperienced workers out of the pen the first day of mating trials. Even experienced workers

preferred to go in pairs if they had to bend over to fix waterers or feeders, as these toms had run up their back on more than one occasion.

It usually took 2 weeks of mating trials for these males to calm down and cease their attacks. Even then they would occasionally run at the observer when he first entered the pen. In the "Blue Bluff Type" of attack and most normal rushes by toms at farm workers, the toms can be pushed back or aside. They usually then strut away and can be ignored. However, pushing these toms usually provoked them into flying at you. The attacking tom could usually be kept at a distance by using a broom or, in extreme cases stopped by a sharp clap on the head. Of all the pens in these two experiments and in other work with toms during mating trials, only toms reared under blue light (especially blue 12L:12D) and placed in red light during this reproductive stage, attacked that consistantly and viciously.

Plasma Androgen Analyses

The average androgen levels in nanograms per ml of plasma are presented in Table 46 for Experiment 1 and 2 analyses of variance of the data are presented in Table 47. The very high values under the red light during the growth and reproductive phases and in the diurnal average in Experiment 1 were due to 2 toms in one pen having unusually high (430-480 ng/ml) androgen levels. These high levels were repeatable over several analyses even though they were about 10X higher than any other values obtained. Despite the apparently large differences in Experiment 1, there were no significant effects as considerable variation occurred among individuals with pens. There were also no significant differences in Experiment 2 which had much lower variation between

Table 46 Male plasma androgen level (ng/ml) at the end of mating behavior trials (43 weeks of age) by growth phase color and regimen and by reproductive phase color (Experiments 1 and 2).

Treatment	Experiment 1[1/] Androgen (ng/ml)		Experiment 2 Androgen (ng/ml)
Growth Phase Color			
White	2.7		4.2
Red	55.3	(4.9)	6.0
Blue	3.7		4.2
Growth Phase Regimen			
Intermittent	2.6		3.6
Diurnal	38.5	(4.9)	6.0
Reproductive Phase Color			
White	5.7		5.2
Red	52.6	(1.8)	5.3
Blue	3.5		3.9
Experimental Mean	20.6	(3.7)	4.8

[1/] The means within the brackets were obtained by eliminating the 2 toms with the unusually high androgen levels (430 & 480 ng/ml.).

Table 47 Analyses of variance of male plasma androgen levels (ng/ml) at the end of mating behavior trials (43 weeks of age) by growth color, growth regimen and reproductive color. (Experiments 1 and 2)

Source of Variation	Degrees of Freedom	Mean Squares	
		Experiment 1	Experiment 2
		Androgen	Androgen
Growth Color (C1)	2	32557.0	39.3
Growth Regimen (R)	1	34823.2	166.1
Reproductive Color (C2)	2	27655.5	22.7
Pooled Error	12	30268.8	102.8
Among individuals Within Pens	36	7821.8**	104.1**
Within Duplicate Samples	54	21.2	1.0
Total	107		

** P 0.01

duplicates and between birds within pens. In an attempt to see if there was any trend between experiments, the two toms with the unusually large values were eliminated from the averages. The new values, in parentheses in Table 46 were much nearer normal. There may be a slight trend to higher androgen values for those birds reared under red light and under diurnal regimens. Toms kept under the blue light environment during the breeder stage appeared to have the lowest androgen levels. However, due to the large variations among birds in the same pens, as well as between pens, these trends are very speculative.

Reproduction

The hen-day egg production percentages for hens maintained under white, red and blue colored lights during the breeding season are plotted by weeks in Figures 22 and 23 for Experiments 1 and 2. The broody control program was started at the end of the mating trials in both experiments. The percentage of hens broody per week was also plotted from the end of the mating trial to the end of the experiment (Figures 22 and 23). By the start of mating trials in Experiment 1, about 80% of the hens maintained under the intermittent "restricted" light had come to an advanced stage of sexual development as indicated by eversion of the oviduct upon abdominal manipulation. Eggs were found in the red and white light pens on the 1L:3D regimen between the 2nd and 3rd weeks after the hens had been placed under restricted light. The females were 27 weeks of age at that time. The time clocks were checked for malfunction and appeared to have been operating correctly. Between the 27th week and the start of the reproductive phase at 37 weeks of age, hens in the white 1L:3D light pens laid an average of 7.5 and 6.5 eggs

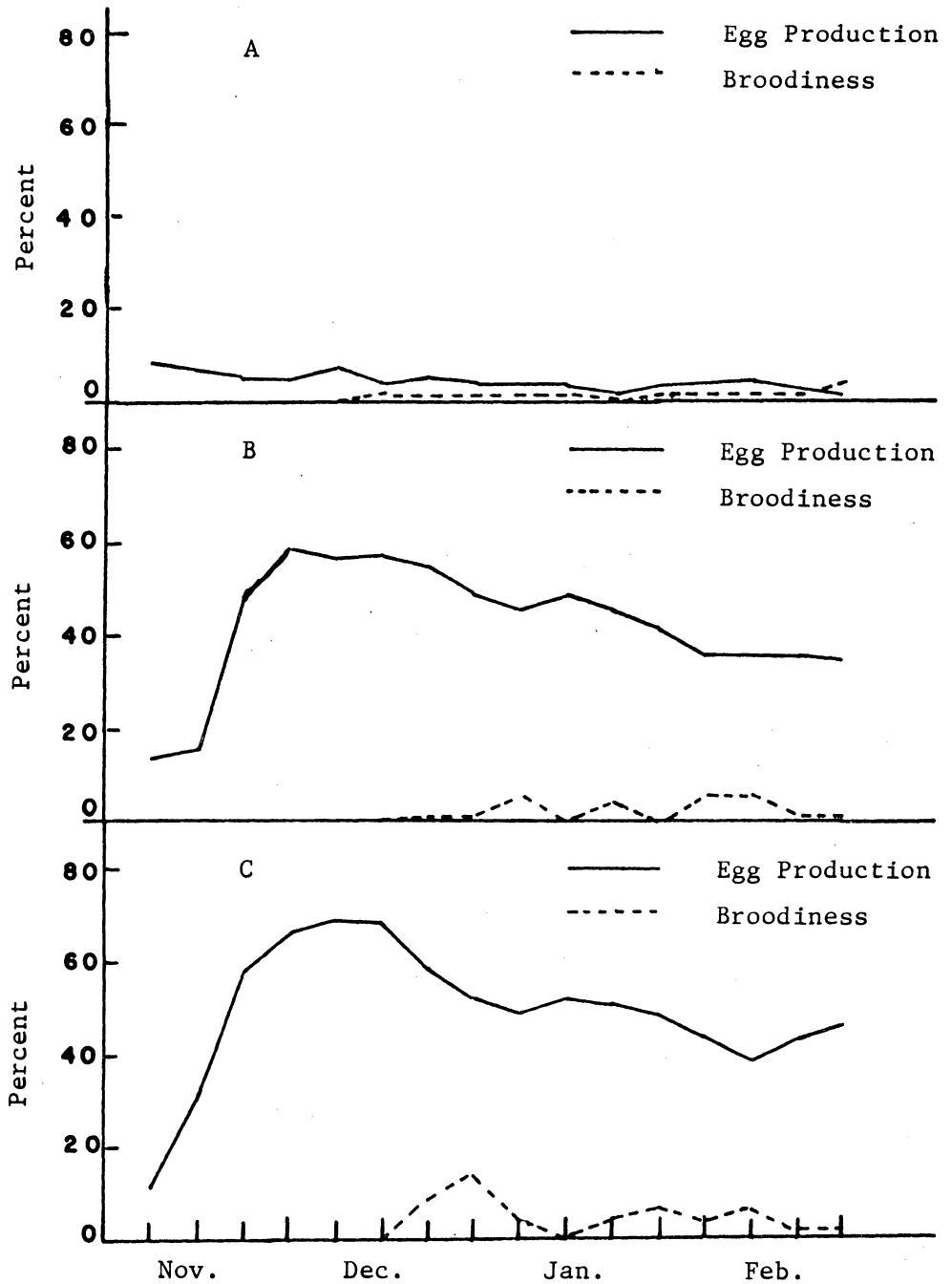

Figure 22. Variation in hen-day egg production and broodiness for hens laying under Blue (A), Red (R) or White (C) light environments (Experiment 1)

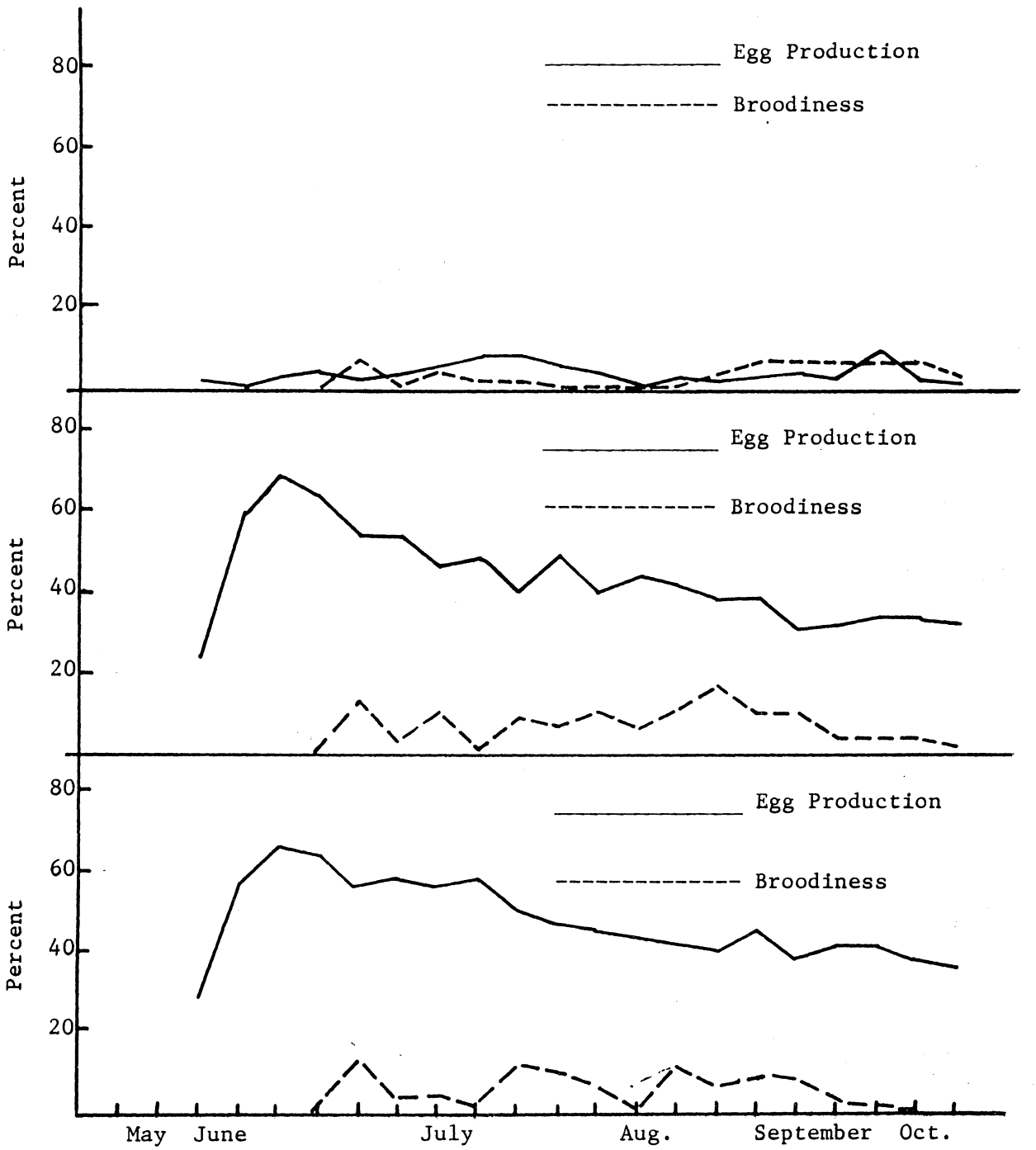

Figure 23. Variation in hen-day egg production and broodiness for hens laying under Blue (A), Red (B), or White (C) light environments (Experiment 2)

per hen and the hens in the red 1L:3D pens averaged 15.5 and 10.5 eggs per hen. At about 32 weeks of age, eggs were also found in one of the red 6L:18D regimen pens. These hens laid an average of three eggs per hen during the following 4 weeks. No time clock malfunction was recorded but these birds had been moved from one building to another just shortly before this time. Although covered by black plastic some birds may have received a brief exposure to sunlight which may have triggered development. The turkeys from the red 6L:18D regimen pen which contained the hens in production were not used in the reproductive phase. This was done because hens on 6L:18D cycles do not normally come into production. No sign of egg production was evident in the other red 6L:18D pen nor in any other 6L:18D pen. It was felt that either a time click malfunction or exposure to sunlight during the movement probably triggered production in this pen. Therefore the hens from this pen would not be representative of the treatment.[1/].

That the hens from the 1L:3D restricted light regimen were laying at the start of the experiment was illustrated by egg production values of between 8 to 15 percent in the first week in Figure 22. Egg production normally does not start until after 10 days to two weeks of stimulatory light.

The average hen-day production in the blue light pens never exceeded 10 percent in any period during Experiments 1 or 2 (Figures 22 and 23). In fact, in both experiments, only 11 or the 48 hens under blue lights during the reproductive phase laid eggs. Of these 11 hens in each experi-

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1/ In Experiment 2 no eggs were found in any of the four pens on 6L:18D red light regimens during the restricted light phase.

ment, 8 were birds that had been raised under white light regimens. In Experiment 1 a total of 47 out of 48 of the hens under white light and 44 out of 48 under the red light during the reproductive phase came into production. In Experiment 2, 47 and 48 hens came into egg production under white and red reproduction light respectively. The light regimen (intermittent vs diurnal) had no consistent effect on the number of hens which laid. The number of hens reared under red and blue light which came into egg production was within 1 bird of each other for both experiments. Allowing for the early start in Experiment 1, egg production patterns (Figures 22 and 23) under red and white reproductive lights appeared normal.

Broodiness was low under blue light. There were no noticable differences in broodiness between hens under red or white lights. Differences in broodiness due to either the growth phase light regimen or wavelength were not apparent except from 15-18 weeks in Experiment 2. In this short period, twice as many of the birds reared under the blue and red growth phase light environments were broody as compared to those reared under white light. Also, in this same time period, hens from the intermittent growth regimen showed about twice as many broody hens as those reared under the diurnal growth regimen.

The average number of eggs per hen to 16 weeks in Experiments 1 and 2 and to 22 weeks of production in Experiment 2 are given in Table 48 and plotted by bar graphs in Figures 24-26. Egg production was significantly higher ($P \leq 0.05$) for hens laying under red and white light as compared to those hens maintained under blue. (Table 49). This can be readily seen by the low bar graph for the blue light pens in Figures

Table 48 Average number of eggs per hen for 16 weeks (Experiments 1 and 2) and 22 weeks of production (Experiment 2) by light color and regimen during the growth phase and light color during the reproductive period.

Reproductive Period		Growth Period					
Production Period	Light Color	Light Color			Light Regimen		Means[1/]
		White	Red	Blue	Intermittent	Diurnal	
Eggs per hen 16 Wks (Exp. 1)	White	59.0	56.8	51.6	55.6	56.0	55.8[a]
	Red	51.5	40.5	51.6	42.1	53.6	47.9[a]
	Blue	11.8	3.1	0.0	6.9	3.1	5.0[b]
	Means[2/]	40.8[a]	33.5[a]	34.4[a]	34.9[a]	37.6[a]	36.2
Eggs per hen 16 Wks (Exp. 2)	White	56.4	52.1	42.9	48.2	52.8	50.5[a]
	Red	55.0	47.6	35.1	46.6	45.2	45.9[a]
	Blue	8.1	3.4	0.1	2.3	5.4	3.9[b]
	Means[2/]	39.8[a]	34.4[a]	26.0[b]	32.4[a]	34.5[a]	33.4
Eggs per hen 22 Wks (Exp. 2)	White	79.3	70.8	52.9	65.2	70.1	67.7[a]
	Red	77.6	61.9	41.0	61.5	58.8	60.2[a]
	Blue	13.0	3.4	0.2	2.8	8.3	5.5[b]
	Means[2/]	56.6[a]	45.4[a]	31.4[b]	43.2[a]	45.8[a]	44.5

[1/] Means within a reproduction period with different superscripts are significantly different ($P \leq 0.05$)

[2/] Means within a growth phase light color or regimen treatment with different superscripts are significantly different ($P \leq 0.05$)

Table 49 Analyses of variance for the number of eggs laid per hen in 16 weeks (Experiment 1 and 2) and in 22 weeks (Experiment 2).

Source of Variation	Degrees of Freedom	Mean Squares		
		Experiment 1	Experiment 2	
		Eggs/Hen - 16 Wks.	Eggs/Hen - 16 Wks.	Eggs/Hen - 22 Wks.
Growth Color (C1)	2	94.3	289.1**	962.6**
Growth Regimen (R)	1	32.6	19.7	30.2
Reproductive Color (C2)	2	4484.2**	3965.2**	6899.9**
Error (Pooled Interaction)	12	59.9	27.9	73.1
Total	17			

* $P \leq 0.05$
** $P \leq 0.01$

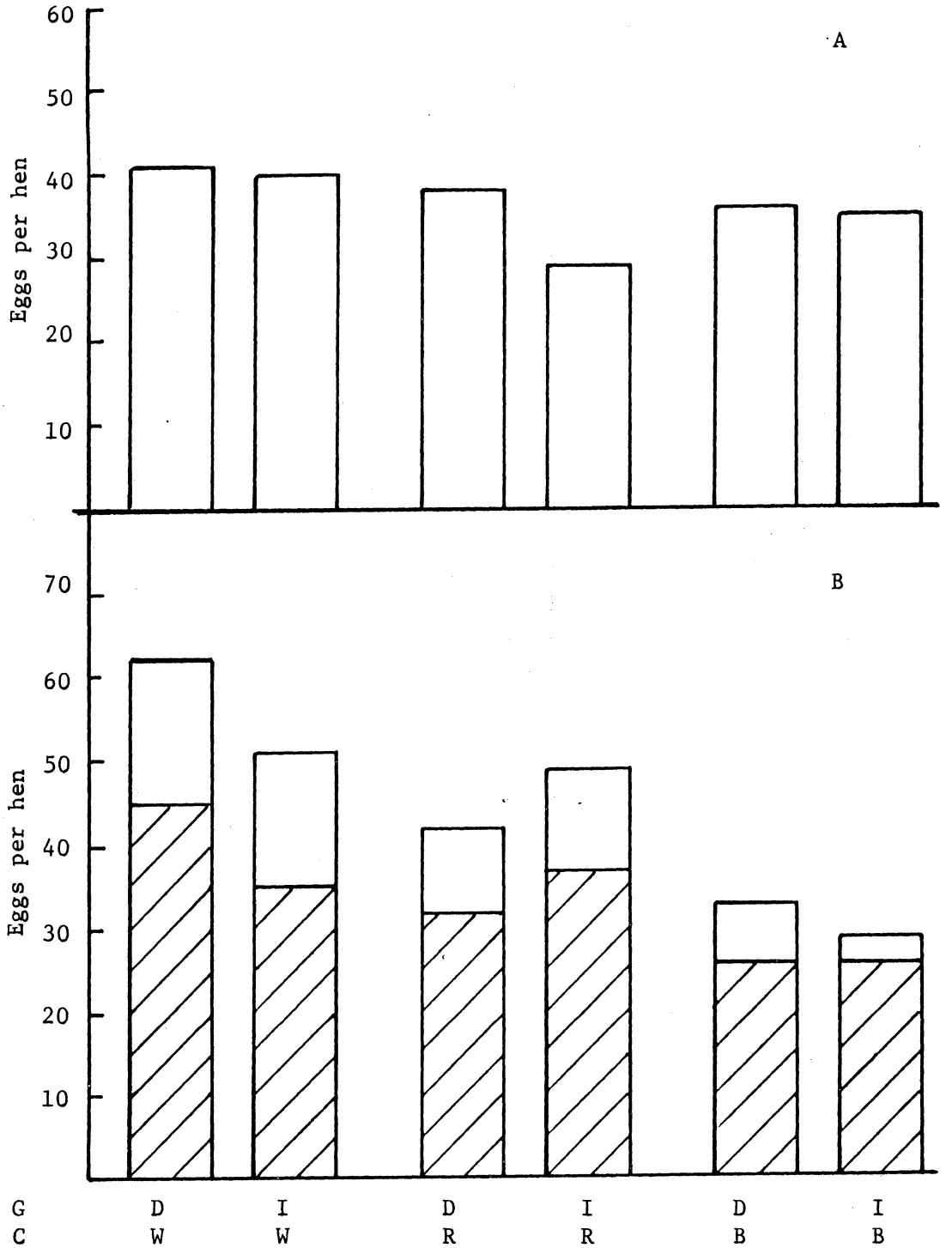

Figure 24. Average number of eggs per hen to 16 weeks in Experiment 1 (A) and to 16 weeks (shaded bars) and 22 weeks (open bars) in Experiment 2 (B) plotted by growth regimen (G) a and growth phase (C) light color. D= diurnal, I= intermittent, W= white, R= red, B= blue

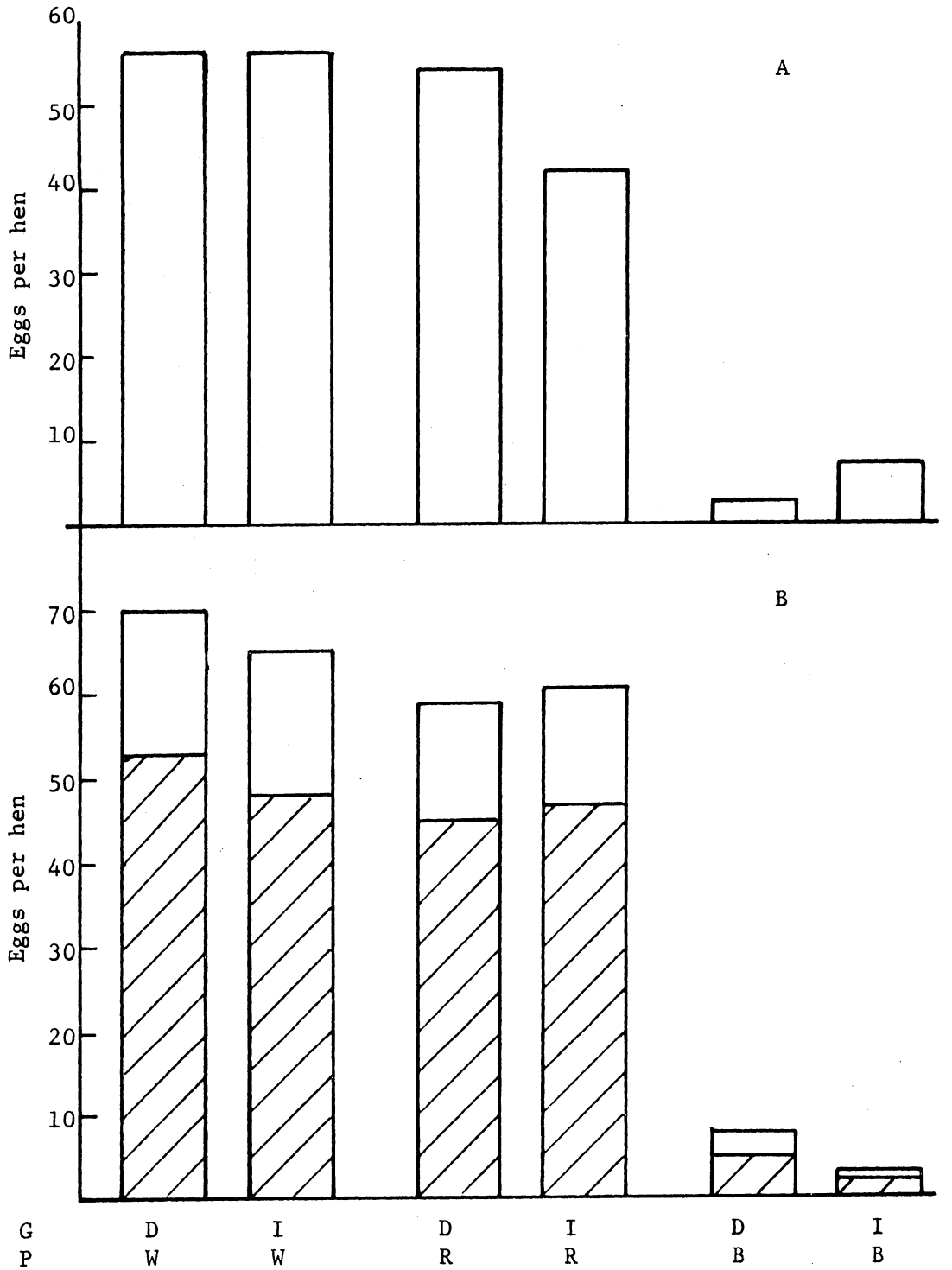

Figure 25. Average number of eggs per hen to 16 weeks in Experiment 1 (A) and to 16 weeks (shaded bars) and 22 weeks (open bars) in Experiment 2 (B) plotted by growth regimen (G) and reproductive phase (P) light color. D= diurnal, I= intermittent, W= white, R= red, B= blue

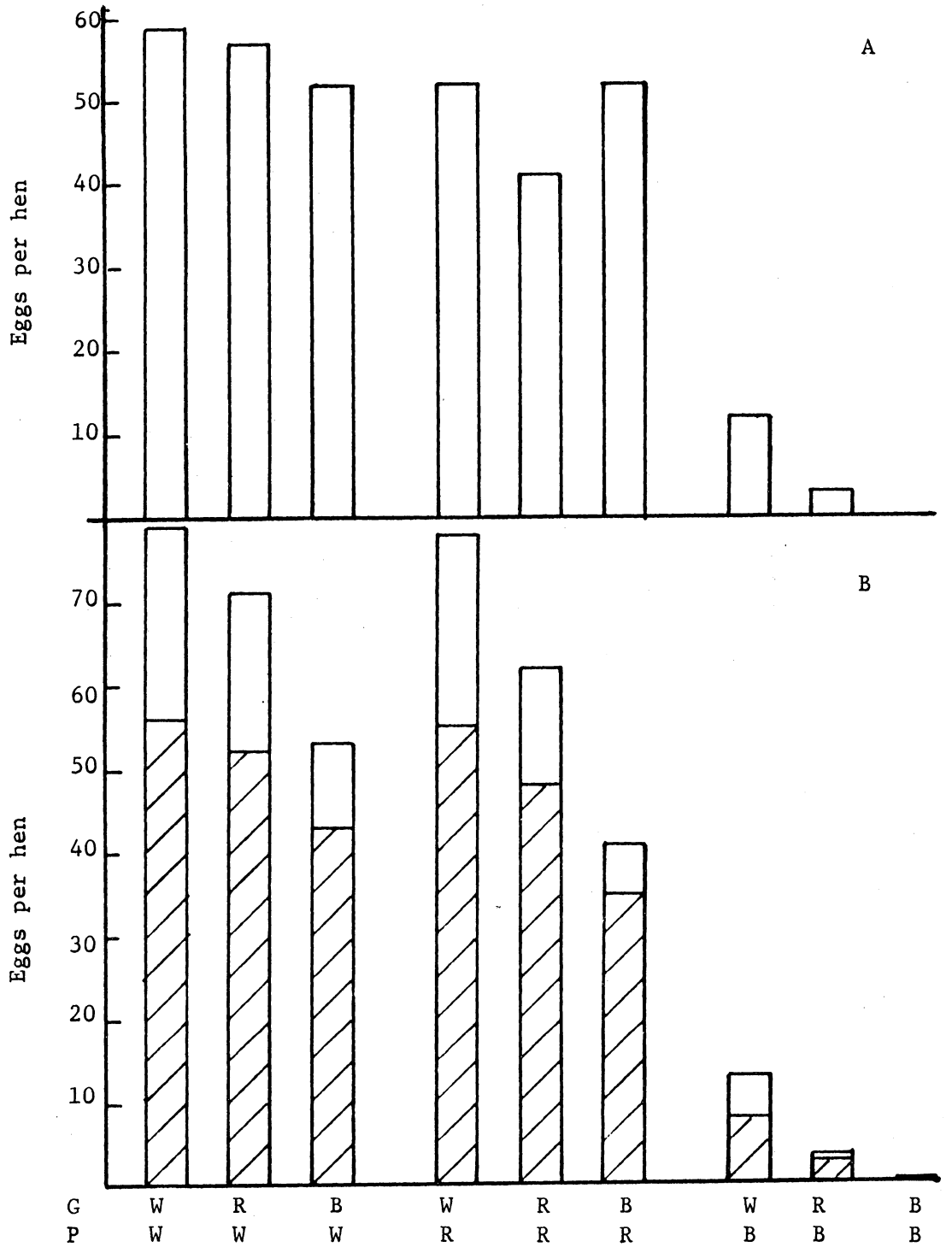

Figure 26. Average number of eggs per hen to 16 weeks in Experiment 1 (A) and to 16 weeks (shaded bars) and 22 weeks (open bars) in Experiment 2 (B) plotted by growth phase (G) and reproductive phase (P) light color. W= white, R= red, B= blue

25 and 26. Production tended to be a shade lower under red lights than white light in both experiments (Figure 25) but the differences were not significant.

As can be seen by the fairly uniform bar height in Figure 24A egg production was not significantly affected by growth regimen or color in Experiment 1. However, the egg production from hens reared under blue light was significantly ($P \leq 0.05$) reduced through 16 and 22 weeks of production in Experiment 2 (Table 49 and Figure 24B).

The average number of eggs per hen to 16 weeks for the growth color by reproductive color treatments are summarized in Figure 26A for Experiment 1 and to 16 and 22 weeks in Experiment 2. (Figure 26B). It should be noted that hens reared under white and kept in white light showed the highest egg production in both trials. Hens reared under white light tended to do the best in all reproductive light colors. Egg production from hens under the red-red was consistently 10 eggs per hen less to the white-white, white-red or red-white color combinations. In both experiments, several hens reared under white or red light laid eggs under blue light. In Experiment 1, hens reared under blue light never came into production when placed under blue light during the breeding season. In Experiment 2, 3 eggs were recorded from hens reared in blue and maintained in blue light pens. As can be seen in Figure 26, virtually no eggs were laid in blue pens by hens from the blue reproductive light environments.

The number of eggs per kilogram of feed are presented in Table 50 for Experiments 1 and 2 by growth color and regimen and by reproductive light color. The main significant effect (Table 51) was the markedly

Table 50 Average number of eggs per kilogram of feed to 16 weeks (Experiments 1 and 2) and 22 weeks (Experiment 2) by light color and regimen during the growth phase and light color during the reproductive period.

Reproductive Period		Growth Period					
Production Period	Light Color	Light Color			Light Regimen		Means[1/]
		White	Red	Blue	Intermittent	Diurnal	
Eggs per kg 16 Wks (Exp. 1)	White	3.2	2.8	3.3	3.0	3.1	3.1^{a}
	Red	2.7	2.2	3.0	2.3	2.9	2.6^{a}
	Blue	0.6	0.2	0.0	0.4	.2	0.3^{b}
	Means[2/]	2.2^{a}	1.7^{a}	2.1^{a}	1.9^{a}	2.1^{a}	2.0
Eggs per kg 16 Wks (Exp. 2)	White	3.6	3.1	3.4	3.2	3.6	3.4^{a}
	Red	2.2	3.1	2.4	3.0	2.9	2.9^{a}
	Blue	0.6	0.2	0.0	0.1	0.4	0.3^{b}
	Means[2/]	1.5^{a}	2.1^{a}	2.0^{a}	2.1^{a}	2.3^{a}	2.2^{a}
Eggs per kg 22 Wks (Exp. 2)	White	2.4	2.9	2.9	2.9	3.3	3.1^{a}
	Red	2.1	2.8	2.0	2.8	2.5	2.6^{a}
	Blue	.7	.2	0.0	0.1	0.5	0.3^{b}
	Means[2/]	2.4^{a}	2.0^{ab}	1.6^{b}	1.9^{a}	2.1^{a}	2.0

[1/] Means within a reproduction period with different superscripts are significantly different ($P \leq 0.05$)

[2/] Means within a growth phase light color or regimen treatment with different superscripts are significantly different ($P \leq 0.05$)

Table 51 Analyses of variance of the numbers of eggs per kilogram of feed to 16 weeks (Experiment 1 and 2) and to 22 weeks (Experiment 2).

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-1}$)		
		Experiment 1	Experiment 2	
		Eggs/kg - 16 Wks.	Eggs/kg - 16 Wks.	Eggs/kg - 22 Wks.
Growth Color (C1)	2	3.3	4.4	8.9*
Growth Regimen (R)	1	1.2	1.3	0.9
Reproductive Color (C2)	2	136.4**	170.1**	133.7**
Error (Pooled Interaction)	12	2.2	1.7	1.7
Total	17			

* $P \leq 0.05$
** $P \leq 0.01$

reduced number of eggs per kilogram of feed for hens housed under blue reproductive lights. This was to be expected due to the very low egg production experienced under blue light. When non-significant interactions were pooled those birds reared under blue lights in Experiment 2 laid fewer eggs per kg of feed consumed (Table 51). This would also be expected as they had laid significantly ($P \leq 0.05$) fewer eggs in Experiment 2. (Table 49).

Semen Production

Male reproductive capacity was determined by measuring the volume of semen produced per collection during artificial insemination. The semen volumes were measured 7 times in Experiment 1 and 12 times in Experiment 2. Seven of the 12 collections in Experiment 2 corresponded to the 7 collections obtained through 16 weeks in Experiment 1. The average semen volume per collection to 16 and 22 weeks of age are presented in Table 52 by growth phase light color, light regimen and by reproductive phase color. As with egg production, semen production was significantly reduced for breeder males maintained under blue light environment (Table 53). These males averaged from 0.10 to 0.13 ml les semen than males under red or white light. Growth phase light environment had no significant effect on semen volume. In Experiment 2, small but significant interactions occurred at both 16 and 22 weeks.

A reproductive color by growth regimen interaction at 16 and 22 weeks suggests that the differences obtained could not be attributed to either growth regimen or reproductive color alone but some combination of those factors. The optimum combinations appear to be an intermittent or diurnal growth regimen with either red or white lights during reproduction

Table 52 Average semen volume (ml) produced per collection from toms milked between 0 to 16 weeks of the reproductive phase (Experiment 1 and 2) and between 0 to 22 weeks (Experiment 2) by light color and regimen during the growth phase and light color during the reproductive period.

Reproductive Period		Growth Period					
Production Period	Light Color	Light Color			Light Regimen		
		White	Red	Blue	Intermittent	Diurnal	Means[1/]
Av. Semen Volume (ml) per Tom per collection 0-16 Wks (Exp. 1)	White	0.24	0.24	0.13	0.21	0.19	0.20^{a}
	Red	0.16	0.19	0.15	0.16	0.17	0.17^{a}
	Blue	0.09	0.06	0.06	0.04	0.10	0.07^{b}
	Means[2/]	0.16^{a}	0.16^{a}	0.12^{a}	0.14^{a}	0.16^{a}	0.15
Av. Semen Volume (ml) per Tom per collection 0-16 Wks (Exp. 2)	White	0.14	0.26	0.19	0.20	0.20	0.20^{a}
	Red	0.24	0.18	0.16	0.23	0.21	0.22^{a}
	Blue	0.08	0.06	0.13	0.06	0.12	0.09^{b}
	Means[2/]	0.16^{a}	0.17^{a}	0.19^{a}	0.16^{a}	0.18^{a}	0.17
Av. Semen Volume (ml) per Tom per collection 0-22 Wks (Exp. 2)	White	0.13	0.26	0.17	0.19	0.19	0.19^{a}
	Red	0.23	0.16	0.22	0.21	0.20	0.19^{a}
	Blue	0.08	0.05	0.10	0.04	0.10	0.07^{b}
	Means[2/]	0.15^{a}	0.16^{a}	0.16^{a}	0.15^{a}	0.16^{a}	0.16

[1/] Means within a reproduction period with different superscripts are significantly different ($P \leq 0.05$)

[2/] Means within a growth phase light color or regimen treatment with different superscripts are significantly different ($P \leq 0.05$)

Table 53 Analyses of variance of the average semen volume to 16 weeks (Experiments 1 and 2) and to 22 weeks (Experiment 2).

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-3}$) Experiment 1 Semen Volume 16 Weeks	Experiment 2 Semen Volume 16 Weeks	Experiment 2 Semen Volume 22 Weeks
Growth Color (C1)	2	4.2	1.3	0.4
Growth Regimen (R)	1	1.7	1.1	0.6
Reproductive Color (C2)	2	26.3*	29.4**	30.4**
C1 X R	2	1.5	3.0	4.4*
C1 X C2	4	2.6	2.2	1.9
R x C2	2	2.3	5.5*	6.2**
Error (C1 X R X C2)	4	3.2	0.5	0.3
Total	17			

* $P \leq 0.05$.
** $P \leq 0.01$.

period. Even in the presence of these interactions, red and white lights during the reproduction period resulted in significantly higher semen production than that obtained under blue lights. At 22 weeks, a growth color by growth light regimen interaction was significant. Those toms reared under white, red and blue diurnal light yielded 0.18, 0.14 and 0.16 ml of semen, respectively. Those reared under white, red and blue intermittent light gave yields of 0.11, 0.17 and 0.17 ml, respectively.

Reproductive Phase Body Weights

Body weights were measured at 0, 8 and 16 weeks in Experiments 1 and 2 and at 22 weeks in Experiment 2. The weights are presented for males and females in Tables 54 and 56 for Experiments 1 and 2, respectively. Analyses of variance of these data are presented in Tables 55 and 57, respectively.

At the start of both experiments (0 weeks) the males and females reared under white and red light were significantly heavier than those reared under blue light. This weight differential due to blue growth light was also maintained throughout the reproductive phase even when the birds were subsequently placed under red or white light. This difference was significant for males and females to 16 weeks in Experiments 1 and 2 and for males to 22 weeks in Experiment 2.

Females reared on the diurnal regimen were significantly ($P \leq 0.05$) heavier at the start than those reared on intermittent light in Experiment 1 (Table 55). However, this difference was not apparent by the end of Experiment 1 and was never seen in Experiment 2. The males reared on diurnal light were significantly heavier at the start of the Experiment

Table 54 Male and female body weights (kg) at the start of the reproductive period (0 Weeks) and after 8 and 16 weeks under reproductive light environments (Experiment 1).

Treatment[1/]	Male Body Weights (kg)			Female Body Weights (kg)		
	0 Weeks	8 Weeks	16 Weeks	0 Weeks	8 Weeks	16 Weeks
Growth Phase Color						
White	11.3^{a}	11.4^{a}	12.6^{a}	6.4^{a}	6.3^{a}	6.6^{a}
Red	11.4^{a}	11.4^{a}	12.6^{a}	6.4^{a}	6.3^{a}	6.6^{a}
Blue	10.6^{b}	10.6^{b}	10.8^{b}	5.9^{b}	5.6^{b}	5.8^{b}
Growth Phase Regimen						
Intermittent	11.2^{a}	11.1^{a}	11.9^{a}	6.0^{a}	6.0^{a}	6.3^{a}
Diurnal	11.0^{a}	11.3^{a}	12.1^{a}	6.5^{b}	6.2^{a}	6.3^{a}
Reproductive Phase Color						
White	11.1^{a}	10.8^{a}	11.7^{a}	6.2^{a}	5.7^{a}	5.8^{a}
Red	11.1^{a}	11.0^{a}	11.7^{a}	6.2^{a}	5.8^{a}	5.9^{a}
Blue	11.1^{a}	11.7^{b}	12.6^{b}	6.3^{a}	6.7^{b}	7.2^{b}
Experimental Means	11.1	11.2	12.0	6.2	6.1	6.3

[1/] Means within each treatment which have different superscripts are significantly different ($P \leq 0.05$).

Table 55 Analyses of variance of male and female body weights at the start of the reproductive period (0 Weeks) and after 8 and 16 weeks under reproductive light environments (Experiment 1).

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-2}$)					
		Male Body Weights			Female Body Weights		
		0 Weeks	8 Weeks	16 Weeks	0 Weeks	8 Weeks	16 Weeks
Growth Color (C1)	2	128.7**	133.8*	643.0**	51.4*	94.7**	119.0**
Growth Regimen (R)	1	30.0	17.8	31.0	88.3**	19.9	0.0
Reproductive Color (C2)	2	0.1	140.2*	168.1**	1.6	189.3**	391.8**
Error (Pooled Interactions)	12	12.7	29.6	22.8	7.9	4.4	5.7
Total	17						

* $P \leq 0.05$.
** $P \leq 0.01$

Table 56 Male and female body weights at the start of the reproductive period (0 Weeks) and after 8, 16 and 22 weeks under reproductive light environments (Experiment 2).

Treatment[1/]	Male Body Weights				Female Body Weights			
	0 Weeks	8 Weeks	16 Weeks	22 Weeks	0 Weeks	8 Weeks	16 Weeks	22 Weeks
Growth Color								
White	12.6^{a}	12.2^{a}	12.5^{a}	13.0^{a}	6.7^{a}	6.3^{a}	6.3^{a}	6.3^{a}
Red	12.4^{a}	11.8^{a}	11.7^{b}	12.2^{a}	6.4^{a}	6.4^{a}	6.3^{a}	6.5^{a}
Blue	11.3^{b}	10.4^{b}	10.6^{c}	11.3^{b}	5.9^{b}	5.7^{b}	5.6^{b}	5.7^{a}
Growth Regimen								
2L:2D	11.8^{a}	11.4^{a}	11.4^{a}	12.0^{a}	6.3^{a}	6.2^{a}	6.2^{a}	6.3^{a}
12L:12D	12.5^{b}	11.6^{a}	11.8^{a}	12.4^{a}	6.4^{a}	6.1^{a}	6.0^{a}	6.1^{a}
Reproductive Color								
White	11.7^{a}	10.6^{a}	10.7^{a}	11.4^{a}	6.4^{a}	5.7^{a}	5.6^{a}	5.7^{a}
Red	12.5^{a}	11.6^{b}	11.7^{b}	12.5^{b}	6.4^{a}	5.9^{a}	5.8^{a}	5.8^{b}
Blue	12.2^{a}	12.2^{b}	12.4^{b}	12.7^{b}	6.3^{a}	6.7^{b}	6.9^{b}	7.0^{b}
Experimental Means	12.1	11.5	11.6	12.2	6.4	6.1	6.1	6.2

1/ Means within each treatment having different superscripts are significantly different ($P \leq 0.05$).

Table 57 Analyses of variance of male and female body weights at the start of the reproductive period (0 weeks) and after 8, 16 and 22 under reproductive light environments (Experiment 2).

Source of Variation	Degrees of Freedom	Mean Squares ($1X10^{-2}$)							
		Male Body Weights				Female Body Weights			
		0 Weeks	8 Weeks	16 Weeks	22 Weeks	0 Weeks	8 Weeks	16 Weeks	22 Weeks
Growth Color (C1)	2	299.8**	515.6**	522.0**	469.6**	111.0**	106.6**	99.8*	103.4
Growth Regimen (R)	1	269.9*	29.1	63.4	55.3	2.2	12.2	23.3	28.3
Reproductive Color (C2)	2	84.9	383.7**	435.4**	306.0*	3.5	166.7**	278.5**	305.2**
Error (Pooled Interaction)	12	42.8	44.6	37.7	47.9	13.5	11.0	20.6	31.1
Total	17								

* $P \leq 0.05$.
** $P \leq 0.01$.

2 reproductive phase (Table 57), but this effect was not observed in Experiment 1 or after 8 weeks in Experiment 2.

At the start of the experiments, there were no differences in the average body weights of the toms or hens transferred to white, red or blue light during the reproductive phase. However, after eight weeks both sexes showed significantly lower body weights in white and red lights when compared to those under blue lights.

Fertility

Fertility and the corresponding analyses of variance tables are found in Tables 58-59 for Experiment 1 and Tables 60 and 61 for Experiment 2. Pens with zero egg production were deleted from the averages. The data tables contain both the averages over all the light treatment and the averages from only the red and white light treatments during the reproductive phase. The number of pens per cell is shown in the parentheses. Due to missing values for several blue light pens in both experiments, only the data from red and white lighted pens were used for statistical analyses.

As expected, the level of fertility due to the natural matings which occurred during the mating trials was very low. Todays modern turkeys do not mate very successfully. Although numerically there appeared to be some differences in fertility under natural mating, these could not be determined statistically because of high variability of this trait (Table 59 and 61). Most of the apparent differences followed the same pattern as CNCM. Where completed matings were low, fertility was also low. For example, fertility under natural matings over all

Table 58 Percent fertility of eggs set[1/] using natural mating and using artificial insemination (to 16 weeks) averaged (a) over all reproductive pens, (b) over white and red colored reproductive pens (Experiment 1).

Treatment	Av. over all Reproductive pens[2/]		Av. over White and Red Reproductive Pens[2/]	
	Natural Mating	Artificial Insemination	Natural Mating[3/]	Artificial Insemination[3/]
Growth Phase Color				
White	44.8 (6)	77.0 (6)	47.6[a] (4)	89.8[a] (4)
Red	14.1 (6)	79.7 (5)	21.1[a] (4)	76.4[a] (4)
Blue	13.3 (4)	83.2 (4)	13.3[a] (4)	83.2[a] (4)
Growth Phase Regimen				
Intermittent	10.9 (8)	73.9 (7)	14.6[a] (6)	79.3[a] (6)
Diurnal	39.9 (8)	84.5 (8)	40.2[a] (6)	87.0[a] (6)
Reproductive Phase Color				
White	27.9 (6)	85.7 (6)	27.9[a] (6)	85.7[a] (6)
Red	26.8 (6)	80.5 (6)	26.8[a] (6)	80.5[a] (6)
Blue	19.6 (4)	65.2 (3)		
Experimental Means	25.4 (16)	79.5 (15)	27.4 (12)	83.1 (12)

1/ Pens without eggs set were excluded from averages.

2/ The number within the brackets indicates the number of pens that had eggs set.

3/ Means within each treatment which have different superscripts are significantly different ($P \leq 0.05$).

Table 59 Analyses of variance of fertility within the natural and artificial insemination periods for data from pens under white and red colored lights (Experiment 1).

Source of Variation	Degrees of Freedom	Mean Squares[1/] ($1X10^{-2}$) Fertility	
		Natural Mating Period	Artificial Insemination Period
Growth Color (C1)	2	60.3	11.7
Growth Regimen (R)	1	108.8	12.1
Reproductive Color (C2)	1	3.2	4.2
Pooled Error	7	50.3	5.9
Total	11		

[1/] Weighted arcsin transformation

Table 60 Percent fertility of eggs set[1/] using natural mating and using artificial insemination from 8 to 16 weeks and 8 to 22 weeks averaged (a) overall reproductive pens (b) over white and colored pens (Experiment 2).

	Av. over All Reproductive Pens[2/]			Av. over White and Red Reproductive Pens[2/]		
	Natural	Artificial Insemination		Natural	Artificial Insemination	
Treatment	Mating	to 16 weeks	to 22 weeks	Mating[3/]	to 16 weeks[3/]	to 22 weeks[3/]
Growth Phase Color						
White	21.1 (5)	84.6 (5)	71.6 (6)	26.4^{a} (4)	88.2^{a} (4)	88.2^{a} (4)
Red	22.9 (5)	89.9 (5)	89.2 (5)	24.4^{a} (4)	92.5^{a} (4)	92.6^{a} (4)
Blue	16.0 (4)	86.5 (5)	86.4 (5)	16.0^{a} (4)	83.2^{a} (4)	83.0^{a} (4)
Growth Phase Regimen						
Intermittent	10.8 (7)	88.3 (7)	76.9 (8)	9.8^{a} (6)	89.7^{a} (6)	89.9^{a} (6)
Diurnal	29.8 (7)	85.9 (8)	86.6 (8)	34.8^{a} (6)	86.2^{a} (6)	86.0^{a} (6)
Reproductive Phase Color						
White	29.6 (6)	89.9 (6)	88.3 (6)	29.6^{a} (6)	88.9^{a} (6)	88.3^{a} (6)
Red	14.9 (6)	86.0 (6)	87.6 (6)	14.9^{a} (6)	86.0^{a} (6)	87.6^{a} (6)
Blue	8.3 (2)	83.5 (3)	63.1 (4)	---	---	---
Experimental Mean	20.3 (14)	87.0 (15)	81.7 (16)	22.3 (12)	87.9 (12)	87.9 (12)

1/ Pens without eggs set were excluded.

2/ The number within the brackets indicates the number of pens that had eggs set.

3/ Means within treatments that have different superscripts are significantly different ($P \leq 0.05$).

Table 61 Analyses of variance of fertility for the natural mating and the artificial insemination periods for data from pens under white and red colored lights (Experiment 2).

Source of Variation	Degrees of Freedom	Mean Squares[1/] ($1X10^{-3}$) Fertility		
		Natural Mating	Artificial Insemination to 16 Wks	Artificial Insemination to 22 Wks
Growth Color (C1)	2	143.5	71.6	79.0
Growth Regimen (R)	1	979.6	22.4	31.2
Reproductive Color (C2)	1	569.7	30.7	0.0
Pooled Error	7	177.7	24.9	24.8
Total	11			

[1/] Weighted arcsin transformation.

pens was 4 and 3 times higher for Experiment 1 and 2 respectively (Tables 58-60) for birds under diurnal light than birds reared under intermittent light. This was the same pattern observed for CNCM's.

In Experiment 1, Table 42 gives a value of zero for cumulative number of completed matings under blue reproductive lights. In Table 57 fertility was reported as 19.6 percent for these same pens. Three of these pens actually showed zero fertility. The fourth pen showed 14 eggs laid, of which 11 (78%) were fertile. The female laying in this pen was possibly mated when the observer was watching a second pen or the door between the male and female pen may have been left open at some time and a mating occurred. Several completed matings were observed in blue pens in Experiment 2.

The use of artificial insemination increased fertility greatly, although Experiment 1 was somewhat below the 85-95 percent level normally achieved at this research station. This was in part due to the fact that artificial insemination did not start until the hens had been laying for up to seven weeks. Normally, for optimum fertility, hens are inseminated at least twice during the first 10 days of egg production. Also, fertility for turkeys normally shows a decline in the later stages of egg production. Fertility was higher in Experiment 2 than 1. This was probably due to the use of weekly insemination used after the first three inseminations in Experiment 2.

Statistical analyses of the data from the red and white reproductive pens revealed no significant differences due to treatments (Tables 59 and 61) in fertility when the females were artificially inseminated. As

well, the averages over all pens contained no consistant pattern of effect due to treatments.

DISCUSSION

Light Environment and Growth

Gill (1973) noted that toms reared under blue light showed a higher body weight gain (BWG) from 4-18 weeks than those raised under white or red light. He also noted that after 18 weeks the rate of BWG under blue light appeared to drop sharply while those under white and red light accelerated so that by the 24th week toms under blue light had a total BWG approximately 0.5 kg less then those under red or white light. While these trends were persistant, they were not statistically significant.

One of the purposes of this project was to further study this response and to see if it was real and whether or not the same principle applied equally to turkey hens.

The growth response observed by Gill (1973) under blue light also occurred for both toms and hens in the present studies. This was dramatically illustrated in Figures 3,4,7 and 8. Some seasonal variation was apparent as the biphasic shift was about 2 weeks slower in Experiment 2 then Experiment 1. Stimulated BWG under blue light was an early growth period phenomena in turkeys. It occurred consistantly from 4-10 weeks. After 10 weeks, the turkeys under blue light maintained this advantage until between 14-20 weeks of age depending on the season and sex. On the average, by 16 weeks of age, the blue light conditions had shifted from a growth stimulatory environment to a growth depressant environment.

Differences in BWG due to wavelength of light have been reported by Lauber and McGinnis (1965), Foss et al. (1967, 1972), Woodard et al. (1968, 1969) and Wabeck and Skoglund (1974). However, there was no

consistant pattern of growth due to wavelength between species.

Interestingly enough, Tamimie (1967) reported pink light depressed early growth while Wabeck and Skoglund (1974) recorded a depressed growth rate from 0-9 weeks among broilers reared under red florescent lights. Those reared under blue or green were heaviest, while white or yellow light produced an intermediary growth response. Foss et al. (1972) speculated that the growth response under green light may be due to the absence of a growth depressing wavelength found in white light. If this were true, then this study would indicate the depressant wavelength would be in red (600-700 nm) region. BWG's were almost identical to 10 weeks of age under either red or white light. In addition the depressing wavelength would only be effective during the early growth period.

Gill (1973) suggested that the growth response of turkeys appeared to be biphasic in nature, dependant upon the quantity (intensity) and possibly the quality (wavelength) of light environment. He showed that early BWG's were highest under low intensity white, red or blue light environments. However, the toms appeared to go through a second growth phase (from about 14 weeks onward) during which the growth rate of the birds under the low intensity light environments dropped sharply. The drop was comparable to that found under the blue light environments in this study. Gill (1973) also pointed out that this decline was somewhat dependant on light quality as it occurred earlier under red and white light than blue light. This would tend to suggest a link with sexual development, or lack of it, under either low intensity or blue light. Red and white light and high intensity lights have been shown to

stimulate sexual development by numerous researchers (Bissonette 1932, Benoit 1964, Touchburn 1970, Nestor and Brown 1971, Gill 1973). However, light intensity was the most notable factor in the occurrence of the biphasic response in Gill's study.

This study employed the high intensity light filter system that was calculated by Gill (1973) to shed approximately 86 lux from the white, red or blue light source. However, measurements conducted during the current study on these sources indicated that the blue light intensity was considerably less then that of the white or red light sources (Table 2). Therefore, the early growth stimulation obtained under blue light in this study may be as much due to low light intensity as to the blue wavelength.

Several comment should be made in regard to the problem of trying to maintain uniform light intensities in studies involving both monochromatic and white light sources. Light intensities are currently being reported in two different measurements. Microwatts/cm^2 ($\mu W/cm^2$) are radiometric units giving a physical measure of the absolute physical energy emitted from the light source. Lux, a photometric unit, is a psychophysical measurement based in part on the intensity of the light source and on the fact that the human eye perceives different wavelengths with different efficiencies. Thus, if a red, a white and a blue light source had equal intensities in $\mu W/cm^2$, they would not have equal values when measured in lux. That is, the red and white light would appear much brighter to a human observed than the blue light (Uttal, 1973). Therefore, if birds are placed under light sources of equal $\mu W/cm^2$, the intensity of light may

appear to be as different to the bird as it would to the human. However, if we try to give equal stimulation in terms of luxes, we run into several probelms. First, we are applying a human psycho-physical scale to a bird whose visual perception sensitivities are relatively unknown. Manning (1972) pointed out that most birds have red, orange and yellow oil droplets in their retina. These droplets would tend to filter out blue light making it appear darker than a red light source of equivalent intensity.

Second, most of the common photometers designed to measure intensity in luxes are also basically designed for measuring white light, but not monochromatic light sources. Therefore, the results may not be accurate. However, a fairly good agreement was found for the red and blue light values in this study between the direct photometer readings and the lux values obtained using an idealized conversion equation from the radiometer (W/cm^2) readings. For example, at 2.13 m from the light source, the lux values for the red light was 96.8 when read directly from a photometer and 90.8 by converting the radiometer units to luxes.

Once you do manage to get equal intensity values (either W/cm^2 or lu es) other factors such as variations in line voltage, old versus new bulbs, age, conditions of filters and dust can alter the daily intensity values. Also, in this study the design of the light source box limited the bulb size for blue light to 500 watts. A larger bulb would have caused a fire hazard or would have melted the filter.

Why blue light and/or low intensity of the blue light caused an increased growth rate has not been determined. Reduced social stress because of poor recognition or through limited visibility has been

suggested. But neither Gill (1973) nor the results of this study could show any difference in adrenal size among treatments due to light color. Adrenal hypertrophy is a commonly used indicator of stress in avian studies. Reduced physical activity has also been proposed. Behavioural observations recorded that a difference in activity did occur. Turkeys reared under blue light were much less active than those under red or white lights. On the other hand, if reduced activity or social stress were the reasons, why the abrupt decline in BWG from 16-24 weeks under blue light? Corresponding changes in behavior or in adrenal weights were not observed for that period.

Red light has been determined as the wavelength that stimulates sexual development (Bissonette 1932, Benoit 1964) while blue light has been shown to have very low stimulatory properties (Scott and Payne 1937, Gill 1973). As mentioned previously Gill (1973) suggested that turkeys appeared to have a two stage (biphasic) growth response dependent upon the quality and quantity of light. He also hinted that this may be tied to sexual development. In the first growth phase (Stage 1) optimum growth occurred under non-sexual stimulatory light situations (i.e. low intensity and/or short wavelength). From our studies and Gill's work (1973), the length of the Stage 1 phase would appear to depend upon light intensity, wavelength and the season of the year. On the average, the transition from the Stage 1 growth phase (best growth under low sexual stimulation) to the Stage 2 growth patterns (best growth under sexually stimulatory conditions) occurred between 14-18 weeks of age. The growth response appears to switch to a Stage 2 as sexual development occurs. In Gill's work (1973) testes development, as measured by weight, tubule size and

spermatogenesis, was significantly greater under red or white light than blue light. Testes development and related parameters were also greater under the high intensity lights. This was evident in necropsies performed on toms at 17 and 23 weeks oa age. This was also the point in time when teh BWG for toms under high intensity or under red or white lights became greater than those under low intensity and/or blue light. The same trend was noticed in the present study for female ovarian and oviduct weights as well as for male testes weight, tubular diameter and spermatogenic stage. However, as there was considerable variation within birds treated alike, the multi-variate analysis on all the necropsy data only showed a significant color effect for the males in Experiment 2. Larger sample sizes, would probably have improved the sensitivity of the analyses. This could not be done due to limited number of birds available for necropsy.

Morris (1967a) concluded that for chickens the intensity of light during the growth period had little effect on the rate of sexual maturity provided the hens received a minimum of 5 lux during the reproductive phase. Morris (1967b) reported that light regimens were the main factor affecting the rate of maturity, and that birds maintained continuously under 10-12 hours of light from day old matured as early and laid as well as those birds reared under 8 hours or less and then increased to 14 hours or more during the reproductive phase. In turkeys, Asmundsen (1946) and Garland (1961) reported that a minimum of 22-25 lux was required in the reproductive phase for the most rapid stimulation of sexual response and the highest rate of lay. However, in more recent work by Thomason et al. (1972), 5 lux stimulated maturity and egg production during the reproductive phase as well as 86 lux for large white turkeys. Nestor and Brown (1972) could

not establish a light intensity effect on the rate of sexual maturity nor on egg production for 3 medium weight turkey strains. However, using large white turkeys, egg production but not sexual maturity increased with intensity (51 lux vs. 18 lux). Nestor and Brown (1972) concluded that each strain should be tested for optimum egg production response to light intensity. It would appear that the age of sexual maturity is not too greatly influenced by light intensity during the growth period Therefore, the intensity of 10 lux under blue lights as used in this study should not have affected the rate of maturity during the growth phase, and the trend toward retarded sexual development would be due to the non-stimulatory properties of the blue wavelength. This would agree with work by Oishi and Lauber (1973) on quail. Ganong (1974) attributes most of the growth spurt at puberty to steroids. These come from the testes in males and from the ovary and adrenals in females. Estrogens also cause increased tissue growth (Turner, 1972) and fat deposition. Therefore, normal sexual development under red and white light could probably account for Stage 2 growth rates, while the decreased BWG under blue light was due to lower levels of circulating steroids and subsequent delay in sexual development.

Although no significant differences were found within each androgen test group, toms under blue 12L:12D light, the least stimulatory light system, showed the lowest average androgen levels 62.5 per cent of the time when compared across all light treatment groups. Better detection of treatment effects on androgen levels could possibly come about by the pooling of plasma samples. Blood samples could be drawn from four or five individuals per pen and pooled. The use of 2 to 3 groups of pooled plasma per pen should reduce the high variation found between individuals, give

more plasma samples on which to do duplicate samples, and give a better indication of the over all pen response.

The trend towards retarded sexual development and lower androgen levels under blue lights from 18-24 weeks of age corresponds well with the lowered BWG's from 16-24 weeks.

The 2L:2D light regimen stimulated larger BWG's for male and female turkeys than the 12L:12D regimen. This effect was most pronounced from 4-16 weeks and was often significant by 10 weeks of age. There were no differences in the 16-24 week BWG's between regimens. Increased BWG under intermittent versus diurnal light has been reported for chickens by Barott and Pringle (1951), Clegg and Sanford (1951) and Shutze et al. (1959). The same effect was reported for turkey toms (Gill, 1973) and hens (Begg, 1973). Buckland (1974, 1975) maintained that intermittent regimen (1L:3D) promoted greater growth than either diurnal or continuous light regime.

Gill (1973) thought that the intermittent growth response was due to precocious sexual development which stimulated growth after 18 weeks in cool weather and 12 weeks in warm weather. He found that testes weights and development were significantly advanced under white intermittent light as compared to the diurnal regimens. Thus, Gill's results appeared to indicate that the occurrence of a Stage 2 type growth response to intermittent light was similar to the response under the sexual stimulatory white or red light environments.

However, in this study the increased growth response under intermittent light occurred largely in the Stage 1 time period under all light colors. By 10 weeks of age this BWG was significantly larger under

intermittent light than the diurnal regimen for both sexes in both experiments. This advantage increased slightly up to 16 weeks in most cases, but from 16-24 weeks of age the BWG was the same under the intermittent versus the diurnal regimens. Therefore, as the intermittent light appears to have had its main effect prior to the period when growth response due to sexual stimulation usually occurred and also under non-sexual stimulatory lights, increased sexual stimulation as proposed by Gill (1973) does not appear to be the whole answer.

More uniform feeding patterns have also been studied as one possible reason for an increased growth rate in chickens on intermittent light (Weaver and Siegel, 1968). However, they found it did not account for all the difference. Also it does not explain why intermittent light has been reported superior to continuous light (Buckland 1974, 1975).

Extra stimulation of the pituitary or pineal gland may occur under intermittent regimens. Unfortunately necropsy data from these studies could show no significant effect on the weights of those glands due to light regimen. That only indicates however, that no gross effect was occurring in these glands. An intensive biochemical and histochemical study of glandular responses in future studies may clarify the relationships between light stimulation and hormone secretion in growth responses of turkeys.

The use of blue light, low intensity light and intermittent light regimens during the early growth phase of young turkeys could provide real economic gains due to increased BWG's. By switching to high intensitities and/or red or white light at around 14 weeks, it may be possible to obtain additional growth responses of the Stage 2 type. This may give

a maximum growth response over the whole growth curve. Intermittent light regimens in light controlled houses could reduce electricity costs and improve the economics of rearing turkeys under commercial conditions.

Blue light regimens and/or lower intensity regimens may also provide the needed early growth responses desired and also make flock management easier. Turkeys under blue light were much more docile and easier to handle. Pens under blue light tended to have lower mortality rates from 10-24 weeks. Turkeys from both blue and red light environments also tended to have better feather scores, indicating the birds were more tranquil.

It was interesting that the poorest feather scores were consistantly observed in birds reared in the white 12L:12D regimen. This would tend to indicate that these birds were more excitable and this was verified in the behavioral observations. The white 12L:12D light pens were the only ones in which cannibalism was apparent and contributed significantly to mortality.

Thus, it would appear that both for growth and management, an intermittent blue light or low intensity white light regimen is more desirable during the first 16 weeks of the turkeys life. At 16 weeks, turkeys should be placed under high intensity red or white intermittent lights.

Light Environment and Mating Behavior

Mating behavior activities are greatly reduced and often cease to be exhibited when turkey's are mated under blue light of 8-10 lux intensity. This intensity is above the threshold level of white light required to stimulate the reproductive processes. Thomason et al. (1972) found no difference in maturity or egg production for turkeys under either 5.4 lux

or 86.1 lux intensity when females were maintained under 16 hours of light per day. Oshi and Lauber (1973) working with quail found that blue light failed to maintain gonadal size even when the intensity was greater than the minimal red or white light intensity required to maintain gonadal size. Therefore, they concluded that the limiting factor for intact birds was wavelength. But they went on to suggest that super high intensity monochromatic blue wavelengths (of the order of sunlight) may be sexually stimulatory, even in blinded birds.

Thus, for the intensities found in most studies such as this one, and which would be commercially practical, red or white light is sexually stimulatory and blue light is not. This study shows that blue wavelengths not only failed to stimulate sexual development but also inhibited sexual behavior. This was especially true if the birds were raised under blue light as well as being mated under blue light. In addition, being reared in blue light and subsequently being exposed to the longer wavelengths of white and red light also appeared to lower general mating measurement.

The rearing and mating of turkeys under white light resulted in optimum overall mating behavior measures. This may suggest that red light, while sexually stimulating, may not be complete enough for optimum expression of sexual behavior.

For both experiments, all mating behaviors measured were consistently lower for toms and hens reared under the intermittent light regimen. However, these values were only significantly different for male sex drive in Experiment 2. Lower male sex drive could account for the poor mating efficiency (Toms from diurnal pens had 2-3 X higher efficiencies) which in turn would account for lower average cumulative number of completed matings.

No logical reason can be put forward at this time as to why the intermittent 1 ght lowered the male sex drive.

In Experiment 1, the lower female values may be explained by the fact that the intermittent light regimen was sexually stimulatory even though only 6 hours of total light per 24 hours was used. It has been demonstrated by Wilson and Abplanalp (1956), by Bell and Moreng (1973)and by Biellier (1974) for chickens and by Wilson (1962), Tanaka et al. (1965) and Bacon and Nestor (1975) for quail that intermittent light can stimulate and maintain egg production. In Experiment 1 most hens from the intermittent regimen were either laying or about to commence laying. Therefore, the peak of their sexual drive was over and they provided little stimulus or opportunity for the males to demonstrate their mating ability. The same overall trend was present in Experiment 2 at about the same magnitude. However, the pattern of occurrence was different. In Experiment 2, the mating behavior responses under intermittent light started our equal to those under diurnal light but declined much more rapidly.

In Experiment 2, one or two eggs were found in the red and white pens on the 1L:3D intermittent restrictive light cycle at about 27 weeks of age. This was the same age as the hens in Experiment 1 had begun to lay. It was felt that egg production during this period was the cause of the low mating activity in Experiment 1 and this interferred with the mating behavior studies. Therefore, all intermittent regimens were switched to the 6L:18D diurnal restrictive regimens in Experiment 2. Egg production ceased and at the start of the mating behavior trials no hens were laying. Egg production was not recorded in any pen until 14 days after the hens were placed under the 16L:8D light cycles. This would indicate that not

only were the hens not laying, but that none of them were even about ready to lay just prior to the start of the trials as had been the case in Experiment 1.

In Experiment 2, the hens which started on the intermittent restrictive light regimens were brought to a stage of near-sexual maturity as indicated by the occurance of egg production and oviduct eversion at 27 weeks of age. Presumably they would have then been in the period of high sexual desire which is normal for turkey hens prior to the start of lay (Leighton 1951, Smyth and Leighton 1953, Carte and Leighton 1969). The hens were then put under 1L:18D and egg production ceased. When these birds were placed on the 16L:8D regimens their sexual behavior responses started out at about the same level but quickly dropped below the average of the birds reared on diurnal light regimens. This raises the following question. If a hen's reproductive system is stimulated to or almost to the point of egg production twice, is the sexual desire of the hen and the persistency of this drive greater during the first stimulation than the second, even though no or very few eggs were laid between the two stimulatory periods? Leighton (1951), Smyth and Leighton (1953), Carte and Leighton (1969) and Schien and Hale (1965) have reported that sexual desire rises after a broody period. However, it does not seem to be as great as that found prior the initial egg production period. Possibly this could account for the trend to lower female mating frequency. This in turn could have resulted in low male stimulation and overall mating behavior values.

Non-Mating Behavior

The placement of turkeys of reproductive age under blue light altered

their general as well as their sexual behavior patterns. Under blue light turkeys generally were very tranquil and showed very little movement about the pen. Most movements by the birds were very slow when compared to turkeys reared under red or white light. Part of this reduced activity may have been due to the lack of sexual activity. Blue wavelengths, even at intensity levels higher than those required by red or white lights, may not be sexually stimulatory (Oishi and Lauber, 1973). Most general behavior patterns were slightly more normal for turkeys mating under white light environments that under red light. The birds maintained under the red light were more excitable and more wary of the observers or workers. However, these changes were minor compared to the changes described for birds under blue light.

Agonistic patterns were the most noticeable and varied non-mating behavior characteristics observed. Two agnostic patterns were noticeable and were very dependent upon the color of lights involved.

Fights between hens and toms were very common in blue reproductive light pens and were usually initiated by the female. Most of the toms and hens involved in these encounters were raised under red light although some had been raised under blue light. Fighting among toms and hens was not noticed for turkeys reared under white light.

The possible reason for this may be two fold. First male-female fighting only occurred consistently in both experiments under blue reproductive lights. In those pens sexual activity was virtually nil and the females did not respond to the males by assuming a sexual crouch. Usually they stood erect and would often challenge the male in much the same manner as a dominance pecking encounter. While it was ofter the same one

or two hens involved in these encounters, it was not determined if they were the dominant hens in the pen. Also, these encounters were normally won by the male turkey. Thus, the low level of sexual response by the female to the presence of the male allowed the expression of other behavioral patterns. While the majority of the females either huddled together or moved slowly about the pen, one or two invariably chose to fight with the males. That they chose to attack the toms suggests that they failed to visually recognize the tom as a male, but considered him to be merely an intruding turkey (perhaps female) in their pen. The lower light intensity of the blue light pens may have contributed to their poor recognition. A second contributing factor may have been degradation of the visual processes for birds reared under red and blue lights. Bercovitz et al. (1972) have demonstrated myopia in chickens reared under blue lights. As well as myopia, continuous stimulation by red monochromatic light could possible lead to deterioration of the cones sensitive to blue light through disuse. Thus birds subjected to red light may have had impaired vision but this was not determined in this study. Birds reared under white light could be assumed to have normal vision and would have less recognition problems. Fighting among toms and hens reared under white lights was not recorded in any of the blue pens.

As indicated earlier, fighting between toms and humans occurred in two distinct patterns. The Blue Bluff Type of attack occurred between humans and toms in the blue reproductive pens. The attach usually was mostly bluff and could be easily terminated by gently pushing the tom

away. This type of attack occurred only in the second experiment and came from males reared under either red or blue lights. This behavior was similar to that sometimes found among males under ordinary light conditions and may have been due to chance.

However, the super-aggressive behavior of those males reared under blue light, especially 12L:12D, and mated under red light was consistant in both experiments and was definitely not a normal reaction. In this type of attack on humans, toms would physically attack much in the manner of a fighting cock and were very persistant in their endeavours. It usually took about 2 weeks of mating trials before the more aggressive toms returned to a less belligerent attitude and began mating activity. Some of this odd behavior may have been due to the poor eyesight, i.e. myopia, caused by rearing under blue wavelengths (Bercovitz et al., 1972). This could account for the disorientation and flying into the walls which often occurred when the males were in the female pen. Myopia plus a possible under development of the cones sensitive to the red wavelengths while subjected to the blue light environment may have lessened the toms ability to recognize objects. This may have caused the toms to react defensively towards the observer as a possible threatening situation. Over time, under the red light, their cones sensitivity to longer wavelengths may have improved and the attacks lessened as the tom could consistently identify the observer and recognize him as not being a threat. However, while this may account for the initial attack, it doesn't account for the viciousness orpersistency of these attacks on the observer.

Androgens have long been implicated in aggressive and sexual behavior. Castration has been shown to reduce sexual and aggressive behavior in

chickens (Goodale, 1913) and turkeys (Scott and Payne, 1943). Testosterone injections have increased the rate of fighting among mature hens (Allee et al., 1939) and castrated quail (Selinger and Bermant, 1966). Testosterone has been reported as facilitating aggressive behavior in pheasants, chicks, ring-doves and quail (Lazarus and Crook, 1973).

Because androgen secretion is stimulated by light presumably the change in testosterone titers initiated the increased aggression, however, work by Young (1961), Jones (1974) and Van Krey et al. (1977) indicated that the action of testosterone was permissive. Testosterone titers in the blood above a threshold level allowed the expression of sexual and aggressive behavior, and higher levels of testosterone did not result in increased rates of behavior. In addition, Van Krey (personal communication) has observed a temporal relationship between the occurrance of aggression and sexual behavior in chickens. In capons, aggression peaks about 7-10 days after the birds received a testosterone injection. Mating behavior replaced aggression about 7 days later. Brain lesions work by Barfield, 1969 and behavioral physiological studies by McCollom et al. (1971), Cook et al. (1972) and Jones (1974), led to the proposal of separate neural centers for aggression and sexual behavior. Testosterone activated the aggressive center first. This behavior was predominant until the maturation of the sexual behavior neural center about a week later. This time relationship between aggression and mating behavior was similar to that found for the turkeys subjected to a blue growth-red reproductive environment and may account for the time sequence of events. The results of McCollom et al. (1971)

(1971) and Jones's (1974) work suggest that the increased aggression was not the result of an increased androgen level.

Work by Lazarus and Crook (1973) and Balthazart and Hendrick (1976) suggest LH and FSH, respectively, as possible hormonal triggers of aggression certain species. Perhaps one of these hormones operates on aggression in turkeys and the light environments upset the normal balance of this hormone.

As can be seen the cause of this super-aggressive behavior has not been resolved and is more puzzling when you consider that it did not occur under white reproductive light which should have been equally as stimulating.

Plasma Androgen in Mature Toms

In this study and in reports by Furr and Thomas (1970) and Snapir et al. (1974) the normal variation in plasma androgen levels is quite large, at least 10 fold. This makes it hard to determine if differences exist between pens where only a small number of birds are available for sampling per pen.

Reproduction

Egg production and semen production were greatly inhibited under the narrow band of short wave blue filtered lights at a level of intensity which stimulates egg and semen production under red or white light. This

is in agreement with work by Scott and Payne (1937) with turkeys, Harrison et al. (1969) with chickens and Woodard et al. (1969) with quail. Comparing the results under red versus the white light, egg production and semen volume were consistently lower under red reproductive lighting. However, the differences were not significant.

In Experiment 2, egg production was significantly higher from hens reared under white or red light than from those reared under blue lights. As this effect was not apparent in Experiment 1, it may have been an effect which occured more readily with birds reared in the winter with than those reared in the summer. Future studies done during those seasons would be needed to determine whether or not this effect was seasonal of if it would occur consistently at any time of the year. If it was reproduceable year round, investigations could be conducted using blue in combination with narrow bands of other wavelengths to try and determine which wavelengths are deficient for optimum performance.

It should be noted that when hens were maintained under blue filtered lights, those hens that had been reared under white light laid from 2-4 times as many eggs as those which had been reared under red light. Also hens from the red growth-red reproductive light combination produced fewer eggs than hens subjected to white lights, either during the growth or reproductive phase. Hens reared and maintained in white light environment laid more eggs than those reared under either red or blue lights. These facts suggest that although red light is sexually stimulating, white light may contain another wavelength needed for optimum egg production. This may be in the green wavelength range, 500-600 nm. Schumier et al. (1968) reported that chickens reared under green light

produced better than those reared under red or white light when they were subsequently exposed to white, red or green colored lights during the reproductive stage.

It has been shown that blue light conditions during the breeding season generally results in less than optimum egg production for quail and chickens, especially when birds were reared under a blue light environment. Production tended to be from 10-50 percent lower than those of the control population. (Harrison et al., 1969 and Woodard et al., 1969). In the present study egg production under blue growth-blue reproductive phase light environments was essentially zero. It would appear therefore that turkeys are more adversely affected by blue light than either chickens or quail.

Reproductive Body Weight Changes

Both hens and toms reared under blue light weighed less throughout the reproductive phase than those reared under red or white light. A reduced body weight at the start had been anticipated in view of the growth phase results. It was not anticipated however, that the weight differences would remain throughout the experiment especially in the toms, when the birds were placed under red or white reproductive lights. Why this effect should be so persistent is not apparent at this time.

Fertility

There wasn't enough data to allow statistical analysis of fertility of eggs from blue reproductive pens during either the natural or artificial insemination periods. However, the eggs available from the blue light pens during natural mating appeared to have a lower fertility. This could

be directly attributed to low mating activity under that light environment. When only red or white light reproductive pens were considered, fertility appeared unaffected by wavelength or growth regimen under either natural or artificial insemination procedures.

Sexual Delopment and Reproduction under Intermittent Light Regimens

The fact that turkey hens would come into egg production on a 1L:3D regimen was somewhat unexpected in the first experiment. The literature describing this type of occurrence was limited to chickens (Wilson and Abplanalp, 1956) and quail (Wilson et al. 1962, Tanaka et al. 1965). Several reports have since become available: Bell and Moreng (1973), Biellier (1974), Bacon (1972), Brown et al. (1972), and Bacon and Nestor (1975). Two of these reports were confined to research station bulletins and two were merely abstracts giving little detail.

Turkey hens in this study matured sexually and maintained egg production on the 1L:3D intermittent light regimen but not on the 6L:18D regimen. Females under both regimens received the same number of hours of light per 24 hour period. Why then was the 1L:3D regimen stimulatory to reproductive development?

It is a well established fact that regimens of 14-16L:10-8D are stimulatory for sexual development and egg production in poultry. On the other hand, regimens with only one light period of 10 hours or less per 24 hours are generally non-stimulatory (Morris, 1967b). However, reports of stimulation of sexual development and activity by intermittent regimens are becoming more frequent as listed below. Egg production under intermittent regimens has been stimulated and/or maintained equal to controls

for chickens (Wilson and Ablanalp 1956, Bell and Moreng 1973, Biellier 1974), quail (Wilson et al. 1962, Tanaka et al. 1965, Bacon and Nestor 1975) and for turkeys in the present study. In most of these regimens (see Figure 20) the total number of hours of light per day are usually less than 10. What then does the standard 14-16L:10-8D regimen have in common with these intermittent regimens which makes them both stimulatory to sexual development in birds?

Murton et al. (1970, 1974) have proposed that the secretion of leutinizing hormone (LH) and follicle stimulating hormone (FSH) required for sexual maturation in many wild birds requires photo-stimulation at two distinct phases in a circadian rhythm. Hamner (1963, 1964) showed that for wild finches the maximum testes weight came from birds held on 6L:6D:1L:11D and 6L:3D:1L:35D regimens. Birds on 6 hours only showed little development. As well, those birds that received an additional hour of light at a time other than 12, 24 or 48 hours after the start of the initial 6 hour light period also showed very little testes weight increase. The 12, 24 or 48 hour factor suggested to Murton et al. (1969, 1970) a light sensitive period oscillating on a circadian rhythm. Murton et al. (1969, 1970) also showed that birds held on 7L:17D regimens do not develop sexually. However, near the end of the lights-on period, a high level of LH secretion occurred. The testes showed signs of LH stimulation (Ledig cell development and lipid granule build up) but very little spermatogenesis. However, if the birds received an additional hour of light 12-16 hours after the initial light period, the testes showed advanced stages of spermatogenesis. Spermatogenesis was much less advanced in birds which received the extra hour of light outside of the 12-16 hour

period. Murton et al. (1969, 1970, 1974) interpreted the advanced spermatogenic development as indicative of stimulation at that time of FSH secretion. Similarly Shellsworth et al. (1975) have shown that very few female budgerigars (less than 30%) lay eggs with only 8 hours of light, but 60% or more came into production when 2 hours of additional light came 12-14 hours after the start of the initial 6 hours of light. Only 30 to 60% came into lay when an extra 2 hours of light was added outside this 12-14 hour period. From the work by Hamner (1963, 1964), Murton et al. (1969, 1970, 1974) and Shellsworth et al. (1975), it would appear that LH secretion is stimulated by light in the early part of the day, within 7 hours after dawn. On the other hand, FSH secretion would appear to be stimulated by light occurring 11-16 hours after dawn (the start of the first light period). Maximum FSH stimulation appears to come from light perceived 12-14 hours after the start of the initial LH stimulatory light period. Therefore, it would appear that as long as the initial light period sufficient to initiate LH secretion is followed by a period of light between 11-16 hours later (FSH stimulatory), sexual maturity could develop equally as well under a 14L:10D, 6L:6D:2L:10D regimens or under a number of various intermittent regimens such as occurred under the 1L:3D regimen in this study.

In regards to domestic poultry, there are now at least 15 light regimens in the literature which have promoted sexual development (Figure 20). Each regimen has at least one fairly long initial light period or 2 short light periods during the first 7 hours. This would form the LH stimulatory period. In 13 regimens, a period of light occurred between 12-15 hours after the start of the original period with 8 of these having

Source	Species	Regimen	Rating M	Rating P
Std. Regimen	C, T, Q	14L:10D		
This study	T	1L:3D		
Wilson and Abplanalp 1956	C(Exp 3)	1.5L:2.5D		L
	C(Exp 4)	0.02L:3.98D		H
Wilson 1962	Q	1L:2D	E	
Tanaka et al. 1965 (control 12L:12D)	Q	3L:3D	H	
		6L:6D	H	
		4L:4D	H	
Bell&Moreng 1973	C	0.17L:3.83D		E
Biellier 1974	C	1L:3.5D & 9.5D		E
	C	1L:5.75 & 9.5D		L
Bacon and Nestor 1975	Q	1L:2D & 9D	E	E
		1L:3D & 8D	E	E
		1L:3D	E	E
		1L:1D &12D	L	L
		1L:3D & 12D	L	L
van Tienovan and Ostrander 1976 (control 16L:8D)	C	2L:12D:2L:8D		E
		1L:7D:6L:10D		E
		2L:4D:8L:10D		E

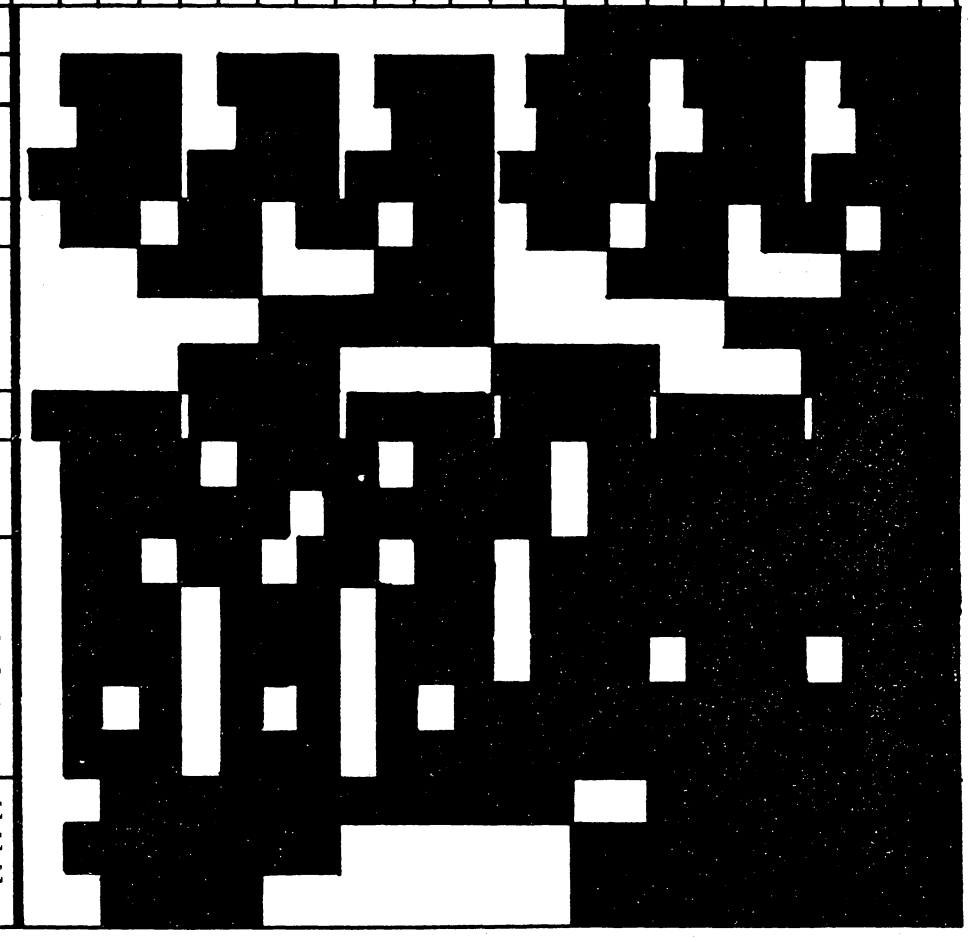

Figure 27. A comparison of a number of 24 hour intermittent light regimens giving the source, species (C= chicken, T= turkey, Q= quail), regimen (L= lights on = white spaces; D=dark periods= black spaces) and a Rating for sexual maturity (M) and egg production (P). Under the ratings L=less that controls, E=equal to controls, H=higher that or earlier than controls. Control regimens were 14L:10D unless otherwise indicated. Each regimen was graphed such that 0=dawn or the start of the first stimulatory light period.

a light period at 13 hours after dawn. Two of the intermittent regimens which had lower egg production than the controls did not have a light period between 12-16 hours after the start of the original period.

Recent work by van Tienhoven and Ostrander (1976) has shown that only two periods are needed as long as one of them falls in a period approximately 14 hours after the start of the other period.

The data displayed in Figure 20 are in agreement with the proposal of Murton et al. (1970, 1974), that sexual maturation and egg production are dependent upon light stimulation between 0-7 hours and 12-16 hours after dawn. The work of Murton et al. (1969, 1970), would appear to indicate that LH secretion is photosensitive to light during the first period while FSH secretion is photosensitive to light during the second period. Stimulation during these periods would be effective irregardless of whether it came from a diurnal or an intermittent regimen.

Tanaka et al. (1974) have shown that a single releasing hormone, luteinizing and follice stimulating releasing hormone (LH-RH/FSH-RH) can stimulate the release of gonadotrophins in chickens. This releasing hormone has been shown to cause the release of both FSH and LH in mammals (Schally et al., 1973). However, bioassay work by Tanaka et al. (1974b) and lesion work by Snapir et al. (1974) with chickens suggests that there are also separate releasing factors for LH and FSH. This would be in agreement with the hypothesis by Murton et al. (1970, 1974).

How these light sensitive periods for LH and FSH release fit into the control of ovulation and oviposition is not yet clear. The level of LH in the pituitary and in the plasma has been reported to have from one to three major peaks in a 24 hour cycle (Harrison et al., 1974). LH and

FSH, both singularily and in combination have been shown to cause ovulation in chickens (Nalbandov, 1976). In fact, the situation is so unclear as to the hormones involved that Nalbandov (1976) in an intensive discussion of the problem prefers to talk about an ovulation inducing hormone (OIH). The identity of this hormone may be LH, FSH, a LH-FSH complex or something totally new. Nalbandov (1976) provides an insight into the complexities of the systems involved.

The purpose of the reproductive phase was to evaluate the effect of the different environmental light colors and regimens during the growth phase on subsequent mating behavior and reproductive capabilities while exposed to either white, red or blue light during the reproductive phase. In light of rising costs, the effect of environmental factors on reproductive capabilities is of practical importance to today's turkey breeder. New techniques claiming to allow the maximum expression of the genetic potential of the turkey, to lower costs and to improve management are proposed daily. We need to know how these factors really will affect the turkey. In addition, it was hoped that the results of these studies would provide a base for future research work.

The use of intermittent light regimens and regimens such as those used by van Tienhoven and Ostrander (1976) gave production rates comparable to those found on conventional 14-16L:10-8D regimens. As most of these regimens used less than 14 hours of light per day they could be useful in the future as a means of cutting electricity costs. However, the advantage would probably be restricted to those climates where enclosed houses are required which would allow adequate light control.

Intermittent light regimens may provide a useful research tool in

discovering how the hormonal control of ovulation and oviposition works and the interactions that exist between light and hormone cycles. Injections of progesterone and LH can either advance or delay the next oviposition and ovulation (Nalbandov, 1976) depending on the time they are given. It would be interesting to see if these time relationships were the same under intermittent light as under standard 14L:8D regimens.

The use of white light during both the rearing and reproduction stages gave the best overall mating and reproductive responses and would be the recommended light source for breeding flocks. The use of red lights during either phase had no beneficial response and would only add to the costs of operation. Blue lights were detrimental to optimum reproductive performance. Also, blue lights should probably not be used with breeding stock during the growth phase, as it appears to reduce egg production at certain seasons.

Intermittent light should not be used with turkey breeders during the growth phase until further work has been done to clarify its effect on egg production. In future work, the use of intermittent lights should be discontinued at earlier ages such as 24, 22, 20 and 18 weeks to see if there is an age dependant effect on reproductive capabilities.

An area of future research that may lead to an interesting psychological study is the superaggressive nature of the toms reared under blue light and placed into red light. Studies should be conducted to determine if this only happens for turkeys, if it is the result of anatomical changes in the eye, or if it is a hormone induced psychological change, possibly of androgen origin.

SUMMARY AND CONCLUSIONS

This study was designed to determine the effect of environmental lighting on growth, reproduction, mating behavior and selected histological and physiological parameters in turkeys. During the growth phase two lines of turkeys, a Large White (LW) and a Medium White (MW) line, were exposed to white, red (650 nm) or blue (450 nm) filtered light on either an intermittent (2L:2D) or diurnal (12L:12D) regimen.

A biphasic growth response was observed due to the colored light environments. Turkeys of both sexes and both lines grew at a faster rate under blue light than under red or white lights up to approximately 16 weeks of age. At that time the rate of growth under blue lights dropped sharply and the body weight gains for the turkeys exposed to white and red light surpassed that of the turkeys reared in the blue light. Early growth appeared to be favored by light environments which had low sexual stimulatory properties (blue wavelengths) while light environments conducive to sexual stimulation such as white or red lights tended to promote maximum body weight gains from 16 to 24 weeks of age for both male and female turkeys.

Intermittent light regimens resulted in significantly greater body weight gains over the diurnal light regimen for both sexes and lines. The primary acceleration in growth rate occurred between 4 and 10 weeks and this growth advantage was maintained through 24 weeks of age. There were no differences in feed efficiency due to light color or regimen by market age or 24 weeks of age.

Early mortality was highest under blue light but late mortality was greater under red and white light. Mortality was higher for the LW than MW birds.

Live market grade was unaffected by light regimen or color. However, feather scores were significantly lower for turkey reared under a diurnal-white light regimen.

Histological and physiological parameters were not significantly affected by light color or regimen. However, those parameters which measured sexual development in the ovaries and testes were generally lower under blue light at 18 and 24 weeks of age then under red or white light.

Turkeys were more tranquil under blue light than under red or white light. Turkeys were also more excitable under the diurnal white light than any other light environment. Light regimen had no apparent effect on general behavior or feather score under red or blue light environment.

During the reproductive phase turkeys were placed under white, red and blue light environments from each growth phase light regimen and color combination. Mating behavior was observed during the first 6 weeks following exposure to 16 hour lights. Measurements of mating behavior parameters were higher among turkeys mated under red or white light than under blue lights. The rearing and mating of turkeys in white light generally resulted in an optimum overall mating response. This was closely followed by the white-red and red-red combinations. However, rearing of turkeys under blue light, especially in the second trial, appeared to reduce mating activity levels.

Mating activity was consistently lower among turkeys reared under intermittent light than among those reared under the diurnal light regimen. This lowered activity was attributed to the sexually stimulatory properties of the intermittent light growth during the phase and the continued use of intermittent light during the restricted light period.

In general, non-mating behavior activity levels were higher in the red and white lighted reproductive pens than in the blue pens.

Turkeys exhibited two types of agonistic behavior. Fight between tome and hens occurred regularly on the blue reproductive pens but rarely in the other pens. Toms from the blue growth phase pens and placed in the red reproductive light environments exhibited a super-aggressive behavior toward any humans which entered their pens. These beligerent and persistent attacks were more pronounced for toms reared under diurnal light regimens.

Egg production was significantly greater for hens in the red and white reproductive light environments than for those under blue lights. Similarly these hens consumed significantly less feed per egg produced to 16 and 22 weeks. Some seasonal differences appeared to be evident.

Turkeys housed under the blue reproductive lights were significantly heavier than those under the red or white lights by the end of the reproductive periods. But turkeys that had been reared under blue growth phase lights were significantly lighter throughout the experiment than those reared under red or white light, regardless of their reproductive light color environment.

Toms under red and white lights during the reproductive season produced greater semen volumes than those under blue light. Light color and regimen had no effect on fertility of eggs set in either experiment.

Egg production was stimulated by the intermittent light regimen used during the restrictive light period. In the second experiment, production was terminated by switching the birds to a conventional diurnal restricted light preconditioning period. Reasons why a restricted light intermittent

regimen may be as sexually stimulatory as that observed when turkeys were exposed to conventional diurnal stimulatory light were discussed.

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APPENDIX A

FEED FORMULATION

Table A-1. - Turkey starter, grower, and finisher diets

Ingredients	Pre-starter (0-4 wks.)	Starter (4-8 wks.)	Grower (8-12 wks.)	Finisher (12-16 wks.)	Fattener (16-24 wks.)
	lb./ton	lb./ton	lb./ton	lb./ton	lb./ton
Ground yellow corn	829	951.5	1074	1196.5	1319
Stabilized fat	70	80	90	100	110
Dehulled soybean oil meal (49% protein)	700	605	510	415	320
Fish meal	150	112.5	75	37.5	--
Meat and bone scrap	100	100	100	100	100
Corn gluten meal	50	50	50	50	50
Alfalfa meal	25	25	25	25	25
Fish solubles	25	25	25	25	25
Defluorinated phosphate	20	20	20	20	20
Ground limestone	10	10	10	10	10
Iodized salt	10	10	10	10	10
Trace mineral mix (turkeys)	1	1	1	1	1
Vitamin premix #1A	10	--	--	--	--
Vitamin premix #1	--	10	10	--	--
Vitamin premix #2	--	--	--	10	10
Total	2000	2000	2000	2000	2000

Table A-2. - Minimum and maximum* nutrient content of acceptable turkey diets.

Nutrients		Pre-starter (0-4 wks.)	Starter (4-8 wks.)	Grower (8-12 wks.)	Finisher (12-16 wks.)	Fattener (16-24 wks.)
Crude protein	%	29	26	23	20	17
Crude fat	%	5.50	6	6.50	7.00	7.50
Crude fiber	%	2.70	2.70	2.70	2.70	2.70
Calcium (min.)	%	1.30	1.20	1.10	1.00	.90
Calcium (max.)	%	1.60	1.50	1.40	1.30	1.20
Inorganic phosphorus	%	.60	.54	.48	.42	.36
Manganese	mg./lb.	25	25	25	25	25
Zinc	mg./lb.	25	25	25	25	25
Preformed vitamin A	IU/lb.	2000	2000	2000	1500	1500
Vitamin D3	ICU/lb.	750	750	750	750	750
Vitamin E	IU/lb.	7	7	7	5	5
Riboflavin	mg./lb.	2.50	2.50	2.50	2.00	2
D-pantothenic acid	mg./lb.	6.50	6.50	6.50	5.00	5
Niacin	mg./lb.	20	20	20	15	15
Choline	mg./lb.	890	760	670	600	530
Vitamin B_{12}	mcg./lb.	9	8	7	6	5
Methionine	%	.60	.54	.47	.40	.33
Antibiotic	g./ton	50	10	10	--	--

* All values presented in the table are minimum values except those for crude fiber which are maximum amounts, and those for calcium which are limits of the range.

Table A-3. Basic turkey breeder diet (TB-2) used in both experiments.

Ingredient	Percentage by weight	Nutrient	Percentage
Ground yellow corn	65.05	Crude protein	18.52
Stabilized fat	2.00	Crude fat	5.33
Dehulled soybean oil meal (49% protein)	12.50	Calcium	2.51
Fish meal	5.00	Inorganic phosphorus	0.669
Meat and bone scrap	5.00		
Alfalfa meal	2.50		
Distillers dried solubles	2.50		
Defluorinated phosphate	1.00		
Iodized salt	0.40		
Vitamin premix[1]	0.50		
Trace mineral mix[2]	0.05		
Ground limestone	3.50		
TOTAL	100%		

[1] Vitamin premix contains the following ingredients per kilogram: vit. A - 2.20 million IU; vit. D - 0.66 million ICU; vit. E - 6.61 thousand IU; Thiamine HCl - 0.22 grams; Menadione-sodium bisulfite - 0.71 grams; Riboflavin - 1.32 grams; Calcium pantothenate (d) - 3.31 grams; Niacin - 8.82 grams; choline chloride - 74.96 grams; vit. B_{12} - 3.31 mg; Folic acid - 0.22 mg; Procain penicillin - 2.20 mg; Ethoxyquin - 24.91 mg; plus a diluent.

[2] Trace mineral mix contains 12% manganese and 12% zinc.

APPENDIX B

DIAGRAM OF LIGHT SOURCE USED TO PROVIDE BLUE & RED FILTERED LIGHT

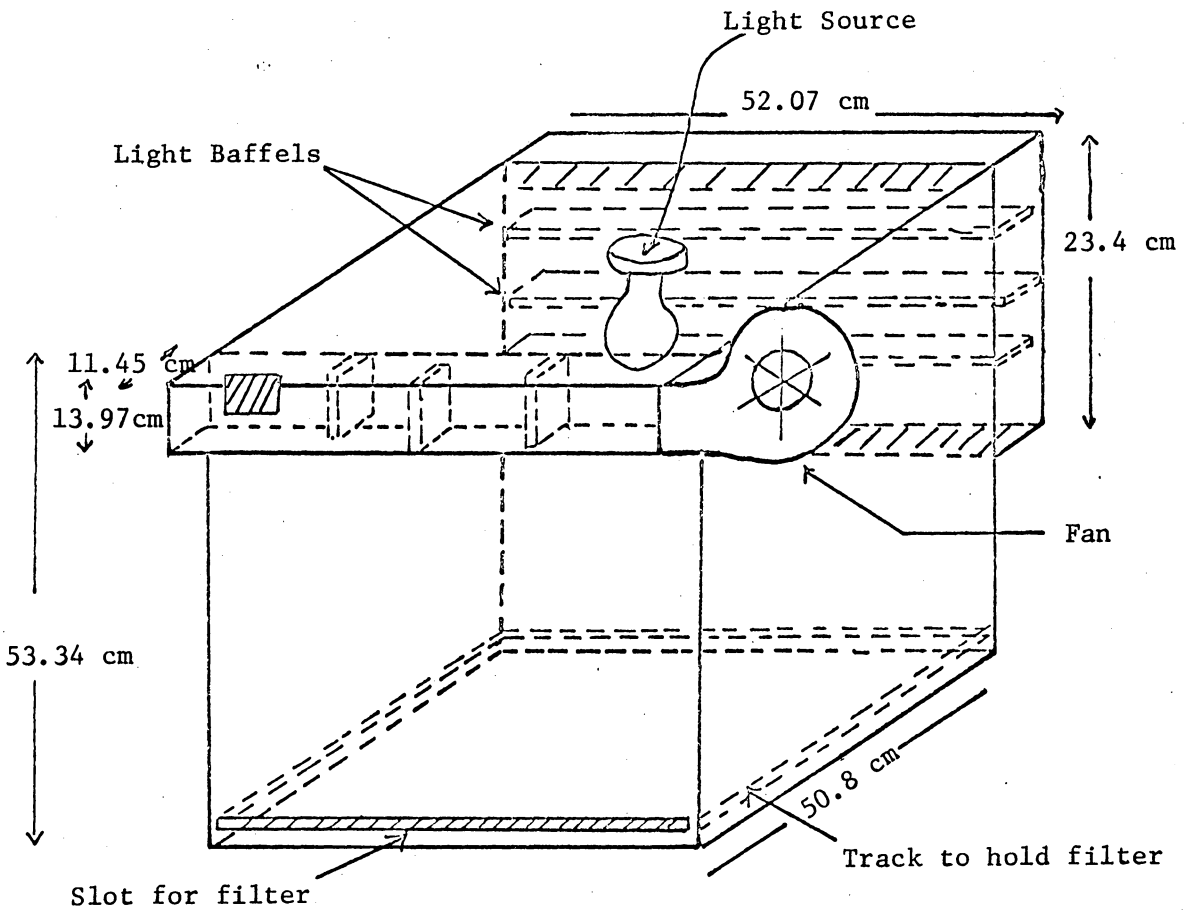

Figure B-1 - Schematic drawing of light filter box used in the growing and breeding pens (After Gill, 1973).

APPENDIX C

ANDROGEN ANALYSIS PROCEDURES

Table C-1. Procedures for determination of accuracy and precision in the competitive protein-binding androgen assay.

1. Dissolve 40 mg testosterone (Nutritional Biochemical Corp.) in 100 ml redistilled ethanol = 0.4 mg/ml.

2. Take 0.1 ml of (1) and Q.S. to 100 ml with redistilled ethanol = 400 ng/ml (stock solution).

3. Take 1 ml of stock solution and Q.S. to 100 ml with redistilled ethanol = 4 ng/ml.

4. Take following volumes of 4ng/ml solution to obtain desired concentration of testosterone and place in 15 mm x 85 mm culture tubes.

50 ul (0.05 ml)	= 0.2 ng
100 ul (0.10 ml)	= 0.4 ng
200 ul (0.20 ml)	= 0.8 ng
250 ul (0.25 ml)	= 1.0 ng
500 ul (0.50 ml)	= 2.0 ng
750 ul (0.75 ml)	= 3.0 ng
1000 ul (1.00 ml)	= 4.0 ng

5. The desired volumes are then dried in a 40°C water bath under air filtered with anhydrous $CaSO_4$.

6. These tubes, which are testing for the accuracy and precision of the method, are then run through the entire extraction and assay procedure.

7. Accuracy and precision tubes should accompany each run of the assay. The number used can be quite variable. Recommend at least 5 tubes for each concentration used in the run.

8. The results are then reported as the accuracy and precision (mean and coefficient of variation, respectively) of the assay technique.

Table C-2. Procedures for determination of % recovery from plasma for CPB androgen assay.

1. Take stock solution of "hot" testosterone (H^3) having known counts per minute (CPM's).

2. Dilute this solution down until you have readable counts on scintillation counter. Do not use less than 100,000 CPM.

3. Take prescribed volume of H^3 testosterone and place in each of 10 (15 mm x 85 mm) culture tubes. These tubes are then placed in a 40°C water bath and dried under air filtered by anhydrous $CaSO_4$.

4. To 5 of "hot" tubes add the volume of plasma used for your samples in the procedure. All of the "hot" tubes are then run through the extraction procedure.

5. Extracts are placed directly into scintillation vials. 8 evaporated to dryness under air.

6. Add 10 ml scintillation liquid and count.

7. Note: Every different volume of plasma used in the experiment should also be tested for % recovery.

8. $$\% \text{ recovery} = \frac{\overline{X} \text{ CPM } H^3 \text{ Testosterone + Plasma}}{\overline{X} \text{ CPM } H^3 \text{ Testosterone}} \times 100$$

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A STUDY OF THE EFFECT OF LIGHT ENVIRONMENTAL LIGHTING ON GROWTH, REPRODUCTION AND BEHAVIOR IN TURKEYS (MELEAGRIS GALLOPAVO)

by

Clifford Keith Levenick

(ABSTRACT)

This study was designed to determine the effect of environmental lighting on growth, reproduction and behavior in turkeys.

During the growth phase a Large White and a Medium White line of turkeys were reared on an intermittent (2L:2D) or a diurnal (12L:12D) light regimens under white, red (650 nm) or blue (450 nm) light environments.

The turkeys grew faster under blue light than under red or white light up to 16 weeks of age. However, by 24 weeks of age, the rates of gain were significantly greater under the white and red lights.

Growth rates were significantly greater under the intermittent regimen as compared to the diurnal regimen for both lines and sexes. The greatest acceleration in growth rate was observed from 4 to 10 weeks of age with this advantage still evident at 24 weeks of age.

There were no significant differences in feed efficiency due to regimen or color.

Early mortality was highest under blue light but late mortality was greater under red and white light. Mortality was higher for the LW than MW birds.

Live grades were unaffected by light regimen or color but feather condition was poorest for birds reared under white diurnal regimen.

The light color and regimen had no significant effect on the histological and physiological parameters measured. However, measurements of sexual development tended to be lower in both sexes for birds reared under blue light.

Turkeys growing under the blue light regimens were the most placid while those reared under the white diurnal regimen were the most nervous.

In the reproductive phase, medium white turkeys from each growth phase regimen and color combination were placed into white, red and blue light pens. Mating behavior measures were higher under red and white light than under blue light. In addition, rearing of turkeys under blue lights appeared to reduce sexual behavior in Experiment 2. For most mating behavior measures, the optimum light color combination appeared to be the white growth-white reproductive light program.

While all mating behavior measures were continually lower for turkeys reared under intermittent light than those reared under a diurnal regimen, these differences were not significantly different.

Turkeys exhibited two types of agonistic behavior. Fights between toms and hens occurred regularly in the blue reproductive light pens and rarely in the others. The majority of the fights occurred among hens and toms reared under red light. Toms from blue growth phase pens and subsequently placed in the red reproductive light environments, exhibited a super-aggressive behavior towards any human entering those pens.

Egg production and semen volume measures were significantly greater for turkeys in the red and white reproductive pens than for those under the blue light conditions.

The hens in the red and white growth pens came into egg production prematurely at 27 weeks of age when maintained on an intermittent light regimen during the growth phase.