Effect of Intermittent Lighting on the Reproductive Performance of First-Year and Recycled Turkey Hens[1,2]

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ABSTRACT In each of two trials, a 2-by-2 factorial arrangement of treatments was utilized to evaluate the reproductive performance of first-year and recycled turkey hens to intermittent lighting (IL) through an egg-laying period of 20 wk. The IL treatment provided 4 h of light per day given as 2 h light:12 h dark:2 h light:8 h dark (2L:12D:2L:8D). This treatment group was compared to controls maintained on 16L:8D. Data were collected for BW, feed intake, feed efficiency, time to first egg, eggs per hen fertility, hatchability, egg weight, and poult weight.

Consistent age effects included greater BW, egg weight, and poult weight from recycled hens compared to first-year hens as well as a delay in the onset of laying and a reduction in egg production by six eggs per hen in the recycled hens. Feed intake and feed efficiency were similar in both age groups. Intermittent lighting delayed the onset of laying but increased the rate of lay by eight eggs per hen. Late-season fertility, feed efficiency, and egg weight were significantly increased by the IL treatment. The conclusion was that, for turkey hens, intermittent lighting can effectively improve reproductive performance.

(*Key words*: turkeys, photoperiod, age, reproductive performance, recycled)

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INTRODUCTION

For many species of birds, the amount of light required to stimulate and maintain reproductive performance need not be given in a single, continuous period (Follet, 1973; Wilson and Siopes, 1976). Rather, the light may be applied intermittently over a 24-h period.

The use of intermittent lighting (IL) has been reported to be effective in maintaining normal, reproductive performance of turkey hens (Bacon and Nestor, 1981, 1982); but no distinct biological advantage was found. However, in a review about the effects of IL on laying fowl, Rowland (1985) noted that there may be improvements in feed intake and production characteristics, but that these responses are highly variable depending on the IL regimen. Siopes (1983) concluded that turkey toms could be maintained more efficiently on an IL regimen of 2 h light:11 h dark:2 h light:9 h dark per day (2L:11D:2L:9D) than on a standard lighting program of 15 h of continuous light per day (15L:9D). Most notable was a persistency in the percentage of normal spermatozoa through the summer heat and a reduction of about 19% in feed intake.

It seems reasonable that an IL regimen that promotes reproductive efficiency would be characterized by a normal activation of the neuroendocrine apparatus regulating reproduction and a total light exposure short enough to reduce activity and, thus, reduce the requirements for maintenance energy. Also of importance would be the provision of sufficiently long light periods for effective management.

The purpose of the present study was to determine the effect of an IL regimen on the reproductive performance of turkey hens. Also, since turkeys may be commercially utilized for more than one egg-laying cycle, the effects of IL were examined for first-year as well as recycled hens.

MATERIALS AND METHODS

In each of two trials, a 2-by-2 factorial arrangement of treatments was utilized to evaluate the reproductive performance of first-year and recycled Large White breeder hens exposed to an IL or standard lighting regimen. The IL treatment provided a total of 4 h of

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[2]The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service nor criticism of similar ones not mentioned.

light and 20 h of darkness per day, given as 2L:12D:2L:8D (lights on at 0800 and 2200 h). This treatment group was compared to controls (C) given 16 h of continuous light per day (16L:8D), with lights on at 0800 h. In both trials, there were four replications for each of the four light by age subgroups. In Trial 1, there were five hens per replicate; in Trial 2, ten hens per replicate.

Immediately before starting the light treatments, all hens were exposed to short daylengths (8L:16D) for 8 wk to ensure that they would be photosensitive when subsequently exposed to the light treatments. In both trials, the first-year hens were started on the light treatments at 32 wk of age. "Recycled hens" are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively. All of the recycled hens had completed two, previous, photo-induced egg-laying cycles, which were at least 20 wk in duration. All recycling was accomplished by photoperiod manipulation only. Induction into laying cycles were preceded by exposure to short daylengths (8L:16D) for at least 8 wk in unselected, but normal, hens that appeared to be healthy.

In both trials, the hens were maintained in closed-confinement in floor pens and were exposed to artificial (incandescent) light only. The light intensity was 54 lx at turkey-head level. Temperature was not controlled. The building was insulated, and the rooms were mechanically ventilated. The two trials were conducted in consecutive fall seasons within the same facility. Feed and fresh water were available on an *ad libitum* basis throughout the study. The feed was a breeder ration calculated to contain 16% CP, 3.05% calcium, and 2,970 kcal of ME/kg of feed.

During the experimental laying period of 20 wk in both trials, the following data were obtained for each pen: rate of sexual development, rate of egg laying, incidence of broodiness (%), percentage of fertility and hatchability, egg weights, poult weights, BW, along with feed intake and feed efficiency. Rate of sexual development was the time required to lay the first egg following exposure to the light treatments. Rate of lay was expressed as the cumulative number of eggs produced per hen after 5, 10, 15, and 20 wk of egg-laying. No distinction was made between floor eggs and nest eggs. Any hen that had ceased egg production, had nested persistently for two consecutive days, and had demonstrated a protective behavior such as hissing was considered to be a broody hen. These hens were immediately removed from the study, but their prior records were included in the data.

All hens were artificially inseminated at the same time of day (1400 h to 1600 h) with pooled semen within 15 min of semen collection. The IL treatment was dark at this time, and dim lights (5.4 to 10.8 lx) were used to facilitate insemination. No pen received more than 10 min of this light. The semen was diluted 1:1 with a commercial extender (Beltsville Poultry Semen Extender), and .025 mL of extended semen was inseminated per hen. Starting at 2 wk after exposure to light treatments, the hens were inseminated weekly throughout the study. Percentage of fertility was determined by candling the eggs after seven days of incubation and breaking-out eggs to differentiate early deads from infertiles. Percentage of hatchability was the percentage of hatch from all fertile eggs. Percentage of fertility and of hatchability were determined at 9, 13, and 18 wk of laying in Trial 1 and at 11, 15, and 19 wk of laying in Trial 2. Eggs were placed in the incubators within 7 days following laying. Poults from these hatches were weighed immediately after removal from the hatcher. Individual egg weights were measured over a seven-day collection period, coinciding with the egg-collection periods for evaluating fertility and hatchability.

Body weight and feed intake were obtained at 2-wk intervals in both trials. Feed efficiency was calculated as the amount of feed consumed per unit of BW per egg produced.

Two-way ANOVA were used to evaluate the treatment effects (photoperiod: C versus IL, and age; first-year versus recycled) according to Steele and Torrie (1980) using the general linear model (GLM) procedure (SAS Institute, 1982). Where appropriate, Duncan's multiple range test was used to estimate significant differences among treatments. The arcsine transformation was used for all percentage data. Three-way ANOVA were used to evaluate trial effects and were applied to all data except those for egg weight, poult weight, and the percentage of fertility and of hatchability, which were displaced in time by about 2 wk between trials.

RESULTS

Following the start of the light treatments, the time to the onset of egg-laying and the rate of egg production are presented in Table 1. No significant trial effects or treatment interactions occurred; therefore, the data were presented for combined trials and as main treatment factors only (photoperiod and age). Both photoperiod and age influenced the onset of laying. The IL treatment delayed egg-laying by 3.8 days (P≤.01); and the recycled hens laid 1.7 days (P≤.05) later than the first-cycle hens. The cumulative number of eggs per hen was similar in both light treatments to 10 wk of laying. At 15 wk of laying, the IL hens produced 4.1 more eggs (P=.08) than the C hens; by 20 wk of laying, this difference had increased to eight eggs per hen (P≤.01). The recycled hens laid fewer eggs than first-cycle hens through 20 wk of laying (58.8 versus 64.4; P=.06). The incidence of broodiness was not different between treatments (2 versus 9 hens in IL and C, respectively, and 5 versus 6 between the first-cycle and recycled hens, respectively).

Within both trials, late-season fertility (18 and 19 wk of laying in Trials 1 and 2, respectively) was better (P≤.01) for the IL than the C hens (Table 2). Age effects were not evident in Trial 1, but fertility was better after 15 and 19 wk of laying in Trial 2 for the first-cycle hens compared to the recycled hens. Neither photoperiod treatment nor age significantly influenced hatchability in both trials (data not shown). Mean hatchability over the three time periods for each of the main treatment factors and for both trials were combined as follows: photoperiod, 72.8 and 67.1% for the C and IL hens, respectively; age, 74.4 and 65.3% for the first-year and recycled hens, respectively.

There was a trial effect (P≤.05), photoperiod effect (P≤.01), and age effect (P≤.01) on mean BW (Table 3). In addition, significant interactions occurred for photoperiod by age and trial by age. Thus, the BW of recycled hens was greater than that of the first-cycle hens; and photoperiod effects were evident only among the recycled hens in Trial 2, where the IL hens were .9 kg heavier than the C hens.

There was no significant trial effect or overall photoperiod effect on feed intake, but there was an age effect (P=.01, Table 3). There was a significant interaction for photoperiod by age and for trial by photoperiod by age on feed intake. Thus, first-cycle hens consumed more feed per kilogram of body weight than the recycled hens; this occurred in both trials with the hens on the C light treatment, but only in Trial 2 for the hens on the IL treatment.

Feed efficiency (grams of feed per kilogram of body weight per egg) was similar for first-cycle and recycled hens in both trials. The mean values were 52.2 g and 52.7 g, respectively, for first-cycle and recycled hens

TABLE 1. *The effect of intermittent (IL) and control (C) lighting and age on the mean onset of egg-laying and on egg production for turkey hens during a 20-wk, egg-laying period, Trials 1 and 2 combined (trial effect P≥.05).*

Main treatment factor[1]	Mean number of days to first egg[2]	5 wk	10 wk	15 wk	20 wk
Photoperiod					
16L:8D, control treatment	19.9^{B}	15.8^{a}	32.2^{a}	46.8^{a}	57.6^{B}
2L:12D:2L:8D, IL treatment	23.7^{A}	13.6^{a}	33.0^{a}	50.9^{a}	65.6^{A}
Age					
First-cycle hens	20.9^{b}	15.6^{a}	33.5^{a}	50.8^{a}	64.4^{a}
Recycled hens[3]	22.6^{a}	13.8^{a}	31.7^{a}	46.9^{a}	58.8^{a}
Pooled SEM	.8	1.0	1.8	2.4	3.1

^{a,b}Means within a treatment factor and within columns with no common superscripts are different (P≤.05).

^{A,B}Means within a treatment factor and within columns with no common superscripts are different (P≤.01).

[1]No significant interactions (P≥.05). L = hours of light, D = hours of dark.

[2]Days following photostimulation.

[3]"Recycled" hens are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively.

TABLE 2. *The effect of intermittent (IL) and control (C) lighting and of age on the percentage of fertility for turkey eggs*

Main treatment factor[1]	Trial 1, week of egg production			Trial 2, week of egg production		
	9	13	18	11	15	19
	(% fertility)					
Photoperiod						
16L:8D, control treatment	89.3[a]	80.1[a]	62.0[B]	83.6[a]	79.0[a]	58.5[B]
2L:12D:2L:8D, IL treatment	90.5[a]	86.2[a]	83.6[A]	88.3[a]	82.6[a]	75.4[A]
Age						
First-cycle hens	88.8[a]	83.3[a]	75.0[a]	87.0[a]	87.0[a]	77.1[A]
Recycled hens[2]	91.1[a]	83.0[a]	70.6[a]	85.0[a]	74.0[b]	56.8[B]
Pooled SEM	1.3	2.1	1.8	1.5	1.5	1.5

[a,b]Means within a treatment factor and column with no common superscripts are different (P≤.05).

[A,B]Means within a treatment factor and column with no common superscripts are different (P≤.01).

[1]Photoperiod by age interaction: P≥.05. L = hours of light; C = hours of control.

[2]"Recycled" hens are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively.

(Table 4). The IL treatments resulted in better feed efficiency than the C treatment in both trials (P≤.01). The mean values were 48.2 g for the hens on the IL treatment and 57.0 g for those on the C treatment. No significant interactions occurred between photoperiod and age regarding feed efficiency.

For egg weight, both an age effect and a photoperiod effect occurred (Table 5). In both trials, egg weight was consistently heavier for the recycled hens (5.9 to 12.3 g) than for the first-cycle hens during each of the three measurement periods. Egg weight was also greater (3.2 to 3.3 g) under the IL treatment during each of the measurement periods for Trial 2. The eggs were also heavier from IL rather than C hens in Trial 1, but the difference was significant only at 9 wk of production.

Poult weight was consistently greater from eggs produced by recycled hens than from first-cycle hens (3.3 to 7.8 g, Table 5). There was no significant effect for photoperiod on

TABLE 3. *The effect of intermittent (IL) and control (C) lighting on mean BW and daily feed intake for first-year and recycled turkey hens during a 20-wk period of egg-laying: significant trial effects occurred for BW but not for feed intake*

Trial	Treatments[1]				
	First-cycle hens		Recycled hens[2]		
	16L:8D (C)	2L:12D:2L:8D (IL)	16L:8D (C)	2L:12D:2L:8D (IL)	Pooled SEM
	BW (kg)				
1	9.2[b]	9.3[b]	10.3[a]	10.8[a]	.31
2	9.9[b]	10.1[b]	10.1[b]	11.0[a]	.26
	Feed intake (g/kg of BW/day)				
1	25.9[a]	21.1[b]	20.6[b]	22.4[b]	.50
2	23.6[a]	23.8[a]	22.4[b]	22.1[b]	.41
X	24.8[a]	22.4[b]	21.4[b]	22.2[b]	.46

[a,b]Treatment means in a row with no common superscripts are different (P≤.05).

[1]Interactions: BW: photoperiod-by-age, P≤.05; trial by age, P≤.01. Feed intake: photoperiod-by-age, P≤.05; trial-by-photoperiod-by-age, P≤.05. L = hours of light; D = hours of dark.

[2]"Recycled" hens are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively.

TABLE 4. *The effect of intermittent (IL) and control (C) lighting and of age on mean feed efficiency (grams of feed per kilogram of body weight per egg) of turkey hens during a 20-wk period of egg-laying*

Main treatment factors[1]	Trial 1	Trial 2	$\bar{x}$
Photoperiod			
16L:8D, control treatment	56.9[a]	57.1[a]	57.0[A]
2L:12D:2L:8D, IL treatment	46.9[b]	49.4[b]	48.2[B]
Age			
First-cycle hens	52.0[a]	52.3[a]	52.2[a]
Recycled hens[2]	51.8[a]	53.8[a]	52.7[a]
Pooled SEM	2.1	1.5	1.6

[a,b]Means within a treatment factor and column with no common superscripts are different (P≤.05).

[A,B]Means within a treatment factor and column with no common superscripts are different (P≤.01).

[1]No significant interactions (P>.05). L = hours of light; D = hours of dark.

[2]"Recycled" hens are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively.

poult weight. No significant interactions occurred between photoperiod and age for either egg weight or poult weight.

Livability was similar in all treatments. Eight of the 120 young hens used in the two trials died, and 5 of these were in the C treatment. Of the 120 recycled hens, only one died.

DISCUSSION

The results of the present study indicated that IL can improve reproductive efficiency for turkey hens while providing a calculated savings of about 75% on the electricity costs for light in closed, turkey houses. This outcome applies to both first-year and to recycled hens. To date, the scientific literature concerning the effects of IL on the reproductive performance of turkey hens generally recognizes an equivalency to standard lighting regimens, but no additional performance benefits. Yet, in the present study, an asymmetric IL regimen providing total light of only 4 h per day (2L:12D:2L:8D) resulted in significant improvements for the rate of egg-laying, late-season fertility, egg weight, and feed efficiency with no adverse effects on any of the other measured parameters.

Presently, more information is available about IL effects on chickens than on other poultry. In a review concerning the effects of IL on chickens, Rowland (1985) reported that asymmetrical IL regimens generally resulted in no change in egg production and feed efficiency, with highly variable effects on egg weight. Symmetrical IL regimens generally depressed egg production and feed intake, but improved egg weight and shell quality. Thus, the benefits of IL may be more pronounced for turkeys than for chickens. However, Bacon and Nestor (1977, 1980, 1981, 1982) reported in several studies about the effects of IL on turkeys that no significant performance benefits occurred. Even so, the specific patterns of IL given in the Bacon and Nestor studies and in the present study were quite different. Hence, it was not surprising that IL regimens with different characteristics could result in very different effects, as illustrated in the review by Rowland (1985).

Feed intake is a major factor in the evaluation of performance efficiency for both the meat and breeder components of the poultry industry. Relative feed intake was not affected by the IL treatment in the present study. However, feed efficiency (grams of feed per kilogram of BW per egg) was better under the IL treatment than the C treatment in both trials from the current study, amounting to a savings of about 8.8 g of feed (15.4%) per egg per kilogram of BW.

The only other full report about IL effects on feed intake or on feed efficiency in turkey hens is that of Bacon and Nestor (1977). They reported that an IL regimen of (1L:2.25D)4:1L:10D, in which the 5 h of light were superimposed over the 14 h, dim-light portion of a 14L:10D lighting regimen, did not significantly affect absolute feed intake (kilo-

TABLE 5. *The effect of intermittent (IL) and control (C) lighting and of age on egg weight and poult weight*

Main treatment factor[1]	Trial 1, week of egg production			Trial 2, week of egg production		
	9	13	18	11	15	19
	Egg weight (g)					
Photoperiod						
16L:8D, control treatment	91.0^{B}	94.6^{a}	94.0^{a}	95.6^{b}	96.9^{b}	96.8^{b}
2L:12D:2L:8D, IL treatment	94.8^{A}	95.3^{a}	95.1^{a}	98.9^{a}	100.1^{a}	100.0^{a}
Age						
First-cycle hens	88.7^{B}	91.0^{B}	91.6^{B}	91.1^{B}	93.1^{B}	94.1^{B}
Recycled hens[2]	97.0^{A}	98.9^{A}	97.5^{A}	103.4^{A}	103.9^{A}	102.6^{A}
Pooled SEM	.8	1.3	.8	.9	.8	1.0
	Poult weight (g)					
Photoperiod						
16L:8D (C)	60.6^{a}	62.0^{a}	62.5^{a}	64.5^{a}	62.5^{a}	61.8^{a}
2L:12D:2L:8D (IL)	61.7^{a}	63.1^{a}	64.4^{a}	66.4^{a}	65.6^{a}	64.5^{a}
Age						
First-cycle hens	57.8^{B}	60.1^{B}	61.8^{B}	62.8^{B}	61.5^{b}	61.0^{B}
Recycled hens[2]	64.5^{A}	65.0^{A}	65.1^{A}	68.1^{A}	66.6^{a}	68.8^{A}
Pooled SEM	.3	1.0	.7	1.1	1.2	1.1

^{a,b}Means within treatment factor and column with no common superscripts are different ($P \leq .05$).

^{A,B}Means within treatment factor and column with no common superscripts are different ($P \leq .01$).

[1]No significant interactions ($P \geq .05$). L = hours of light; D = hours of dark.

[2]"Recycled" hens are those exposed to the light treatments at 102 and 87 wk of age in Trials 1 and 2, respectively.

grams per bird) or feed efficiency (amount of feed per egg produced), compared to a 14L:10D lighting regimen. They did note, however, that the IL treatment favored feed efficiency by 4 to 6% depending on the strain.

Siopes (1983) reported that intermittent light (2L:11D:2L:9D) resulted in a 19.2% reduction in relative feed intake by turkey toms during the summer, compared to toms on a light cycle of 15L:10D daily. The relative feed intake of first-year hens in the present study was greater than that of the recycled hens. In addition, feed efficiency was quite similar for the first-year and recycled hens.

The primary cause for improved feed efficiency under the IL treatment seems to have been the greater egg production by this group, compared with the other groups. How IL improved the rate of laying by a margin of eight eggs per hen from that obtained on 16L:8D is not clear. It seems reasonable to assume that IL was either more effective in stimulating the neuroendocrine system regulating ovarian function than 16L:8D or that the effect was of an indirect nature. The latter could involve such factors as changes in BW and feed intake or others, such as behavioral alterations including broodiness. But the present results indicated that none of these factors were involved. Bacon and Nestor (1977, 1980) also reported that broodiness was not an important factor in terms of the effects produced by IL treatment.

Yearling turkey hens are commonly recycled into a second egg-laying period. Leighton *et al.* (1971) showed that first- and second-cycle, egg-production levels were equivalent for Medium White turkeys. But with Large White hens, a reduction of about seven eggs per hen occurred during the second cycle when the hens were exposed to incandescent light. Yet, egg production was equivalent in both cycles when the hens were exposed to full-spectrum, fluorescent lighting (Siopes, 1984). Cleaver *et al.* (1986) reported that egg production from Large White turkeys was improved during the second cycle of egg-laying.

In the studies mentioned, the cycle comparisons were confounded by displacements in time, among other factors. There is only one other study, in addition to the present one, in which performance comparisons for first-year and recycled hens were made simultaneously under the same management conditions. Thomason *et al.* (1976) reported that for Large White turkey hens, egg production was similar for first-year and recycled birds under the given management conditions. In the present study, recycled hens were slightly delayed (1.7

days) in starting to lay eggs and produced about six fewer (P = .06) eggs per hen than the control hens. The discrepancy between the two studies may be in the fact that our hens were in their third laying cycle.

Information about the influence of IL treatment on fertility and hatchability is sparse. Bacon and Nestor (1977) reported that fertility and hatchability were not affected by an IL treatment of turkey hens during the first 84 days of egg production after 50% of the hens were laying. The present study is in agreement, but also demonstrates that late-season fertility benefited significantly by virtue of the IL treatment.

The percentage of fertility was consistently greater for the IL treatment group at every measurement point in both trials, but significant differences for the controls occurred only late in the laying period. The reasons for the IL-induced improvements in fertility are not known. However, since IL can alter oviposition times (Rowland, 1985), it is possible that the daily oviposition distribution was different for the two treatment groups. One report suggests that the fertility of turkey eggs can be influenced by the relationship between time of insemination and oviposition (Christensen and Johnson, 1977). Since all of our hens were inseminated at the same time, at least some of the effect on fertility probably was due to differences in the daily distribution of oviposition times within each treatment group. A second possibility is that the differences in fertility were the result of differences in the relationship between first insemination and the onset of laying. Because of a mean delay of about 4 days in the onset of laying for the IL-treatment hens, the effective first insemination was given earlier than with the control hens. McIntyre *et al.* (1986) reported that early insemination improved fertility in turkey hens.

The age of the hens influenced the percentage of fertility in that the fertility of eggs from first-year hens persisted at a higher level during the late season than for those from recycled hens. Thomason *et al.* (1976) also noted lower fertility among recycled hens. The age of the hens did not significantly affect the percentage of hatchability in either trial, even though the eggs from the recycled hens had an average hatchability of 9.1% less over the two trials than the controls. This outcome agrees with the report by Thomason *et al.* (1976).

As expected, eggs from the recycled hens were significantly larger than those from the first-year hens, and the resulting poults were also significantly larger. Eggs from hens under the IL treatment were larger than those from the C-treatment hens. Even though the poults were consistently heavier, they were not significantly different from those from eggs produced by the C-treatment hens. The authors are not aware of any other reports about the effects of intermittent light on egg or poult weights in turkeys. However, several studies of egg weight have been conducted with chickens; the results vary considerably depending on the specific characteristics of the IL pattern (Rowland, 1985). Many factors can influence egg weight, including the common ones: rate of lay, body size, and feed intake. In the present study, BW and feed intake were generally similar between the C and IL treatment groups. Rate of lay probably was not a major factor, since a common observation indicates that egg weight is inversely related to rate of lay. The time of oviposition can also influence turkey egg weight (Bacon and Nestor, 1982). As noted previously, it is likely that the oviposition patterns were quite different between the two treatments administered by the authors. In chickens, intermittent light seems to lengthen the time intervals between ovipositions and to allow for increased egg weight (Rowland, 1985).

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