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DIFFERENTIAL EFFECTS OF LIGHT UPON FECUNDITY IN *TRIBOLIUM CASTANEUM*

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ABSTRACT

The effect of light upon fecundity of two genetic strains (black and wild type) of *Tribolium castaneum* was investigated by using continuous darkness, continuous light and an alternate light/dark treatment. Both strains laid significantly fewer eggs in continuous light than in continuous darkness or light/dark; egg numbers recovered in the latter two conditions were similar. A significant interaction was observed between genotype and light treatment and was attributed to many fewer eggs being laid by wild-type females than by black females when exposed to continuous light. Reduction in egg numbers laid was attributed in part to a reduction of normal activity of mating as directly influenced by the sudden introduction of light without prior acclimation.

INTRODUCTION

Relatively little is known concerning the influence of light upon the fecundity of flour beetles of the genus *Tribolium*. In a study designed primarily to examine suitability of oviposition site, Stanley and Grundmann (1965) reported that for the confused flour beetle, *Tribolium confusum* Jacquelin duVal, significantly greater egg numbers were laid in darkness than in normal room illumination. Hawk *et al.* (1974) reported that egg laying rate for the red flour beetle, *Tribolium castaneum* (Herbst), was lower when mated adults were exposed to light under different temperature levels than when they were exposed to complete darkness.

The purpose of the present study was to explore further the effects of light on fecundity in *T. castaneum*, and to check the uniformity of response in different genetic strains under differing light regimes.

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MATERIALS AND METHODS

The two populations of *T. castaneum* used in this study were derivatives of broad-based, randomly mating, heterogeneous base populations differing only by a single genetic marker, black body color (*b*). The populations, derived originally from the Purdue + and *b* Foundation Stocks, have been maintained in our laboratory since 1963.

All beetles were reared in complete darkness in a Sherer-Gillett walk-in environmental chamber operating at 32 ± 1°C and 70 ± 2% r.h. on a standard medium of whole wheat flour and dried brewer's yeast (95:5 ratio by volume). Each stock culture was contained in a rectangular plastic box (17.8 × 12.7 × 6.2 cm) containing 200 g medium and experimental observations were made on single pair matings in 20 ml glass coffee creamers containing 5 g of triple sifted standard medium to facilitate recovery of eggs.

The study was conducted in 8 replications over an 8-month period, each replication, with the exception of Replications 6 and 8, consisting of 15 single pair matings per light treatment. Replications 6 and 8 had only 10 single pair matings due to an unexplained increase in mortality prior to initiation of the treatment period. To initiate each replication, approximately 200 pupae were collected and sexed from each population which, under our normal laboratory conditions, were reared in complete darkness. The pupae were kept in single-sexed groups until eclosion and then the required number of adults were mated, have been randomly selected from these surviving. All paired beetles were kept in complete darkness for 15 days, and were then transferred to fresh creamers with "egg medium" and placed in their respective light treatments for 24 h.

The experimental photic conditions to be compared were: (1) continuous light for a 24-h egg-laying period, (2) continuous darkness for a 24-h egg-laying period, and (3) an egg-laying period in 12 h of light followed by 12 h of darkness (hereafter referred to as the light/dark treatment). The light/dark treatment was coordinated with a fixed day-night cycle; i.e., 0800 hours to 2000 hours (8:00 a.m. to 8:00 p.m.). The light source was provided by five overhead flourescent lamps (Silvania 40W, Cool White-HO) in the environmental chamber, approximately 1.8 m from the culture containers.

All eggs laid by each female during the 24 h period were recovered and counted. Fecundity of the beetles was measured following the procedure outlined by Park and Davis (1945), using a linear egg counting stage (Muir and Grossman, 1973) for the counting process. Hatchability (number of eggs hatching expressed as a percentage of the number of eggs laid) was measured only during Replication 5. This was measured as follows: eggs were counted, returned to the flour, and all larvae hatching from the eggs were counted 96 h later.

RESULTS AND DISCUSSION

Fecundity of the two genetic strains differed; black (*b*/*b*) consistently laid more eggs under each of the three light treatments (Table 1). Egg production for both strains under continuous light was significantly lower than that under either continuous darkness or light/dark. The fecundity values recorded for these latter two treatments were not greatly different.

The analysis of variance (Table 2) revealed that there was also significant interaction (G × T) between genotype and light treatment. The major contributor to this interaction was the degree of response by each genotype to each light treatment. Decreased egg production for the wild-type strain in continuous light compared to that in complete darkness was proportionately greater than the decrease noted for the black strain under the same treatments. Though nonsignificant, differences in fecundity observed between the continuous darkness and the light/dark treatments behaved in a similar fashion. Clearly the reduction of egg numbers due to continuous light exposure is an indication that a suboptimal environment was created for both strains, however, their reaction to the suboptimal environment was different. Similar genotype by light interactions were not observed by Hawk *et al.* (1974); thus, further exploration of the implications of this interaction is desirable, particularly as it may affect overall fitness of the strains involved.

One additional measure of fitness can be provided by hatchability. There was no obvious effect of light *per se* upon egg hatchability, although the overall hatchability of wild type was considerably higher than that observed for black (Table 3). Neither did there appear to be any significant interaction for this variable.

The fecundities measured are net values, and the analysis of fecundity is for beetles of restricted age and known history under favorable constant physical conditions except for light. *Tribolium* adults are normally photonegative (Park, 1934), tending to cluster in shaded portions of their culturing container and then crawling into the medium when exposed to direct light for a period of time. Observations showed that the experimental beetles in this study reacted in the same manner during the treatment periods.

Park (1934) reported that most copulation occurs on the surface of the medium with prolonged tunnelling to escape light tending to reduce the frequency of copulation. Thus, when mating activity is reduced, the number of eggs laid is likely to be reduced since an absence of the stimulation of recopulation would be coupled with a direct discouragement of egg laying due to exposure of light.

The lower rate of fecundity observed under continuous light can further be explained by the lack of acclimation of the adults to light exposure. Cloudsley-Thompson (1953a,b) reported that the strong photonegative response exhibited by *Tenebrio molitor* L. was ameliorated after prolonged exposure to light, with near normal activity of adults on the surface being observed.

Similarly, Arbogast and Flaherty (1973) showed that light response for both *T. castaneum* and *T. confusum* is positively correlated with the state of reproductive development of the beetle. Their study showed that young adults were extremely inactive when exposed to light but the intense photonegative response decreased as reproductive maturity increased, with stabilization of the intensity of light response being achieved by the sixteenth day . This latter was attributed to a speculation that mating activity tended to decrease the photonegative response exhibited in *T. castaneum*, particularly since their experimental animals were reared in alternating light-dark conditions before testing. Thus, beetles reared under constant darkness before being exposed to continuous light, as in the present study, would be expected to take some time to get accustomed to the light before resuming normal copulation. Reduction in copulation would then be expected to effect a reduction in the number of eggs being laid, and any difference in fecundity would be due to the immediate effect of light.

Hawk *et al.* (1974) also have reported reduction of fecundity in *T. castaneum* when exposed to continuous light. However, by the end of the third successive egg laying period, they noted that the photonegative response was less obvious, and that the difference between fecundity levels of their two treatment groups was less striking, probably due to acclimation.

The failure to observe larger differences than those realized in fecundity for the continuous darkness and light/dark treatments is of concern. Initial exposure to light may well have disrupted the normal surface activities of the beetles, but they compensated for the disruption very rapidly when once again introduced to darkness. Whether exposure to light affects not only mating activity, but also oviposition activity remains to be seen, although our data suggest that this may be the case.

While light apparently affects fecundity through reducing mating activity, there is no evidence from our study that fertility (measured by hatchability percentages) similarly suffers. Hawk *et al.* (1974) also have reported that light exposure does not adversely affect hatchability percentages.

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Table 1. Fecundity values[a] (Mean ± standard error) for two genetic strains of *Tribolium castaneum* under three light treatments.

Genotype	Number of females	Light treatment: Continuous darkness	12 h:12 h light/dark	Continuous light
b/b	110	24.6 ± 0.12	23.6 ± 0.15	18.9 ± 0.12
+/+	110	17.8 ± 0.09	17.1 ± 0.20	13.5 ± 0.07

[a]Number of eggs/female/24-h egg laying period.

Table 2. Analysis of variance for fecundity of two genetic strains of *Tribolium castaneum* under three light treatments.

Source of variation	d.f.	Mean square
Genotype (G)	1	6517.38**
Treatment (T)	2	1620.74**
G × T	2	30.63**
Error (corrected)[a]	654	0.45

**$P < 0.001$.
[a]harmonic mean.

Table 3. Hatchability[a] for two genetic strains of *Tribolium castaneum* under three light treatments.

Genotype	Light treatment: Continuous darkness	12 h:12 h light/dark	Continuous light
b/b	87.3 ± 0.75	88.8 ± 0.89	86.4 ± 0.70
+/+	96.3 ± 1.57	96.4 ± 1.57	97.7 ± 1.20

[a]Expressed as percent eggs hatching.