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POPULATION PERFORMANCE AND CHRONIC GAMMA RADIATION*

MASTER

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*This paper is based on work performed under United States Atomic Energy Commission Contract AT (45-1) - 1830

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ABSTRACT

POPULATION PERFORMANCE AND CHRONIC GAMMA RADIATION*

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Modifications of population performance measured as reproductive capacities are of concern in radiation ecological studies because such changes are usually detrimental to the species and will be selected against by natural selection. This paper reports the performance of flour beetle (Tribolium confusum Duval, "chicago standard" and T. castaneum Herbst, "sooty") populations during 18 months of chronic gamma (^{60}Co) radiation. For both species, 5 replicate populations, begun with 20 pairs of virgin beetles, received 24, 49 or 170 R/day. Populations were established at 25 and 32 C at 70-75% RH on 5 g of standard food 8 months before radiation. At monthly censuses numbers of larvae, pupae and adults were determined and with eggs were given new food.

T. castaneum was reproductively more fit than T. confusum at 25 and 32 C with no radiation and at 25 C with 49 R/day; T. confusum was more fit at 32 C and 49 R/day and at 170 R/day in both temperatures. The dose rates used are not feasible for insect control. At 25 C the reproductive performances were reduced yet comparable at 24 and 49 R/day. At 170 R/day extinction was observed. Larvae were more radiation sensitive than adults. When larvae were present, numbers of adults failed to increase indicating that larvae failed to metamorphose. Parameters of radiosensitivity were accentuated at 32 C.

Radiation effects are explained radiobiologically: developing immature stages characterized by growth and cell divisions are more radiosensitive than adult stages characterized by no growth and few cell divisions (except for meiosis). Responses to radiation are determined by interactions among temperature, dose rate and species.

Radiation ecology should consider the physical-chemical-biological interrelationships for several generations in order to assess and predict the consequences of radiation in the biosphere.

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INTRODUCTION

Mutations are the raw material of evolution. Radiations can cause an increase in the mutation rate but Natural Selection determines whether or not the mutant is beneficial. Genetic consequences of radiations are of great concern for maintenance and propagation of a species. Yet the complexities associated with studying natural populations in radiation environments has produced little data in order to predict hazards on the population level from the ever-increasing amounts of radiations in our biosphere. This paper concerns the chronic radiation of flour beetle populations during 18 generations. The data from this radiation ecological research apply to the genetic flexibility of two flour beetle species and relate to the control of grain infesting insects by radiation.

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MATERIAL AND METHODS

Populations of virgin, sexually mature flour beetles Tribolium confusum Duval "chicago standard" and T. castaneum Herbst "sooty" were begun with 20 pairs in 5 g of standard food (95% stone ground whole wheat flour plus 5% brewer's yeast) in lucite test tubes. Environmental conditions were 25 or 32 C in 70-75% relative humidity. Five replicate populations of both species were positioned in concentric rings from a ^{60}Co source (gamma radiation) such that 24, 49 and 170 R/day were obtained. Before being subjected to radiation the populations were censused monthly for 8 months (Erdman, H.E., 1970. Res.Pop.Ecol. XII-1: 61-70). Censusing continued during the 18 months radiation period and consisted of determining the numbers of larvae, pupae and adults which along with eggs were placed on new food. These productivity measurements defined the population performance.

RESULTS

Data from the 24 and 49 R/day dose rates were not significantly different; therefore, data from the 49 and 170 R/day dose rates are presented and referred to hereafter as the low and high dose rates, respectively. Significance refers to the 0.05 level.

Accumulative Dose

The calculated accumulated doses of gamma radiation to flour beetle populations which were chronically exposed during

18 months varied from 11,700R at 24R/day to 82,739 R/day at 170 R/day (Table 1).

Population Performance Measured by Reproductive Abilities

25 C

Adults - Species Comparisons

The comparative responses illustrating a species effect to chronic gamma radiation at 25 C are shown in figures 1 and 2 for the low and high dose rates, respectively. After 13 months of chronic low dose rate gamma radiation exposures, "sooty" was more tolerant than "chicago standard". At the high dose rate at 25 C, "chicago standard" performed better than "sooty"; but, extinction of both species was obvious.

Larvae

Numbers of larvae for both species (Figs. 3,4) progressively decreased and never appeared to contribute to the adult population which also progressively decreased with time. At 25 C and a dose rate of 49R/day (gamma radiation), "sooty" was better adapted than "chicago standard".

32 C

Adults - Species Comparison

At the low dose rate for "sooty" the mean numbers of individuals decreased from 60 to 20 from months 1 and 18, respectively (Fig. 5); whereas, for "chicago standard" they maintained a plateau of approximately 40 to 50 individuals per population, indicating the superior fitness of "chicago standard" under these conditions. At the high dose rate the mean

numbers of adults of both species rapidly decreased and became extinct (Fig. 6)

Larvae

At the low dose rate greater numbers of larvae were found for "chicago standard" than for "sooty" (Figs. 7 and 8, respectively); the variability was concomitantly greater for "chicago standard". Given time such variability could provide this species with a selective advantage. For the duration of the experiment few, if any, larvae became adults because the adult populations segments never showed a substantial increase. For both species at the high dose rate the numbers of larvae reached zero within 6 months.

Population Attributes of Two Species of Flour Beetles

Developmental time was approximately doubled at the low temperature compared to that at the high temperature (Table 2). The time and radiation dose required for extinction were less at the high temperature and greater at the low temperature. Greater radiation sensitivity is associated with highly metabolic tissues or those undergoing rapid cell divisions, both of which increase with increases in temperature.

SUMMARY

1. For both temperatures, "sooty" maintained a larger population than "chicago standard" in the absence of radiation, but in a radiation environment "sooty" was less fit than "chicago standard" except at 25 C and 49R/day.

2. The data showed that 170R/day of chronic gamma radiation would control (that is, result in extinction) flour beetles populations within the temperature range for their survival.

3. Dose rates up to 170R/day of chronic gamma radiation do not seem feasible for control of flour beetles because, (a) the long period of time required for extinction and (b) the possibility of re-infestation.

4. Responses to radiation, such as population performance measured as reproductive capacities, are determined by the interactions among temperature, dose rate and species. Radiation ecology should consider the physical-chemical-biological inter-relationships for several generations in order to assess and predict the consequences of radiation in the biosphere.

Table 1.

CALCULATED ACCUMULATED DOSES OF GAMMA RADIATION DURING CHRONIC EXPOSURE OF FLOUR BEETLE POPULATIONS TO ^{60}Co AT TWO DOSE RATES DURING 18 MONTHS

MONTH	24 R/DAY	170 R/DAY
0 March	240	1700
1 April	1056	7581
2 May	1548	10962
3 June	2195	15551
4 July	2980	21106
5 August	3546	25115
6 Sept.	4443	31472
7 Oct.	4851	34359
8 Nov.	5402	38265
9 Dec.	6114	43309
10 Jan.	6776	48000
11 Feb.	7367	52179
12 March	8014	56763
13 April	8734	61149
14 May	9366	65629
15 June	9970	69913
16 July	10587	74287
17 August	11197	78608
18 Sept.	11780	82739

MEAN NUMBERS OF ADULTS ± STANDARD ERRORS OF FLOUR BEETLES REARED AT 25 C, 70-75 PERCENT
 RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT 49 R/DAY.

Figure 1

MEAN NUMBERS OF LARVAE $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 25 C, 70-75 PERCENT
RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT DOSE RATES OF: 49 R/DAY $\circ$
170 R/DAY $\times$

Figure 3

MEAN NUMBERS OF LARVAE $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 25 C, 70-75 PERCENT
RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT DOSE RATES OF: 49 R/DAY $\circ$
170 R/DAY $\times$

Figure 4

MEAN NUMBERS OF ADULTS $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 32 C, 70-75 PERCENT RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT 49 R/DAY.

Figure 5

MEAN NUMBERS OF ADULTS $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 32 C, 70-75 PERCENT RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT 170 R/DAY.

Figure 6

MEAN NUMBERS OF LARVAE $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 32 C, 70-75 PERCENT
RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT DOSE RATE OF: 49 R/DAY ●
170 R/DAY ×

Figure 7

MEAN NUMBERS OF LARVAE $\pm$ STANDARD ERRORS OF FLOUR BEETLES REARED AT 32 C, 70-75 PERCENT
 RELATIVE HUMIDITY AND SUBJECTED TO CHRONIC GAMMA (^{60}Co) RADIATION AT DOSE RATES OF: 49 R/DAY $\circ$
 170 R/DAY $\times$

Figure 8

Table 2

RELATIONSHIP AMONG TEMPERATURE, DEVELOPMENTAL TIME,
GAMMA RADIATION DOSE AND THE GENERATION IN WHICH EXTINCTION
OCCURRED FOR POPULATIONS OF FLOUR BEETLES

Temperature	T. confusum	T. castaneum
24C Develop. Time (Days)*	53	51
25C No. Generation Extinct larvae/adults	6/>18	8/18
Gamma Ray Dose (R)	31,472/>83,000	38,265/82,739
34C Develop. Time (Days)*	26	22
32C No. Generation Extinct larvae/adults	8/14	4/9
Gamma Ray Dose (R)	38,265/65,629	21,106/43,309

*Park, T., and M. B. Frank 1948. Ecol, 29: 368-374