EFFECTS OF SUBOPTIMAL TEMPERATURE IN *TRIBOLIUM CONFUSUM* AND *T. CASTANEUM*

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Abstract

An "acclimation effect" to high (37°C) and low (22°C) temperatures was investigated using a malathion susceptible strain of Tribolium confusum and a malathion susceptible and a malathion resistant strain of T. castaneum. Populations of these strains had been reared for many generations at 27°C and then treated by rearing for 1 generation at 37°C or 22°C. Following temperature treatment they were reared for the next generation at the same temperature and the other suboptimal temperature. Factors recorded to assess effects were number of progeny, length of developmental time and oven dry weight. T. confusum was found to be more tolerant of the high temperature if its parents had been reared at the low temperature. The same general pattern was observed for the malathion resistant strain of T. castaneum. The pattern changed with the malathion susceptible strain of T. castaneum where a significant tolerance to the low temperature was observed in the length of development time when the parents had been reared at the high temperature.

In January 1983, a United States-Israel Binational Agricultural Research and Development (BARD) project was funded jointly to the Stored-Products Department, Agricultural Research Organization, Israel, and the Stored-Product Insects Research and Development Laboratory, Agricultural Research Service, United States Department of Agriculture for a study entitled "Protection of Grain from Insect Damage through Storage in Semiarid and Arid Regions." The Israeli investigators were Moshe Calderon, Principal; and Ezra Donahaye and Shlomo Navarro, Co-principals. In the United States, Robert Davis was the Cooperating Investigator. The project was divided into two parts with both a field (Figure 1) and a laboratory phase conducted in Israel and only a laboratory phase conducted in the United States. This paper will report on a portion of the research conducted in the United States.

The literature provides us with an abundance of information on the adverse effects of adding and removing thermal energy to grain as a potential insect control procedure. The use of low temperatures has been

Proc 4th Int Work Conf Stored-Product Protection, Tel Aviv, Israel, Sept. 1986
[Eds E Donahaye and S. Navarro], pp. 547-554

Figure 1. 250 ton plastic mobile silo in Israeli desert at Asheleim.

reviewed by Mullen and Arbogast (1984) and the use of high temperatures in food plants by Sheppard (1984) and in stored grain by Kirkpatrick and Tilton (1973). Howe (1965) provides us with information on the minimal and optimal temperature conditions for population increase and the fact that the maximum temperature for most stored-product insects is usually less than 5°C above the optimum. Therefore it was believed by the investigators that semiarid and arid regions of the temperate and tropical areas of the world might provide low enough temperatures during the winter nights and high enough temperatures during the summer days to suspend insect activity or to create a lethal habitat. Any acclimation effect in the pest species to high and/or low temperatures could affect such an attempt to control insects in stored grain.

The phenomenon of acclimation to temperature has been reviewed by Prosser (1973) for animals generally and by Mutchmor (1967) for insects. Baldwin (1954) and others have distinguished between two types of acclimation, one of a physiological nature in which an increase in tolerance occurs in adults that have been exposed to a sublethal temperature for a relatively short time and another of a developmental nature in which a tolerance to sublethal temperatures occurs during the organism's development. Neither of the above definitions precisely fit the study undertaken, however we use the term "acclimation" as we feel it fits better than other available alternatives.

In this study we attempt to elucidate whether or not acclimation could be expected to play a role in long-term storage where high and low ambient temperatures were used as control interventions. The insect populations investigated were a malathion susceptible population of the confused flour beetle, *Tribolium confusum* Jacqulin du Val, and a resistant and a susceptible population of the red flour beetle, *T. castaneum* (Herbst).

Materials and Methods

The insects used in this study were from stock colonies maintained at 27$\pm$1°C, 60 $\pm$ 5% RH and 12-12 h light-dark cycle in the insectory at the Stored-Product Insects Research and Development Laboratory, Savannah, GA, USA. All colonies had been maintained at these conditions for several years. Temperatures selected for testing were 22$\pm$1°C and 37$\pm$1°C. The light regime during the study was variable but the relative humidity level was maintained unchanged. The medium used throughout was the standard medium used in the Savannah Laboratory's insectory for *Tribolium* and was composed of a mixture of white wheat flour, white cornmeal and yeast in a ratio of 10:10:1.5 parts by volume (Bry and Davis, 1985).

In establishing the experimental conditions the P_1 adult population acquired from the insectory was divided into 3 groups. One group continued to be maintained at the "optimal temperature" of 27°C. Of the remaining two groups one each was placed into one of the two treatment temperatures (22 or 37°C). The F_1 progeny from each of the temperature treatment tests were divided into two groups. One group was returned to the same temperature and the other group transferred to the other treatment temperature. Each condition was replicated five times. Each replicate consisted of 200 unsexed 2-3 week old adults in a 0.95 liter glass jar filled one-third with the standard *Tribolium* rearing medium. The adults were allowed 3 days on the medium for egg laying and then were removed and dried in a vacuum oven at 15 psi for 24 hr at 90°C.

Data recorded were the number of adult progeny, time of development to the first adult and dry weight of the adults. Replicates were dismantled 14 days after the appearance of the first adult. All data was treated by ANOVA and Duncan's New Multiple Range test (P = 0.01).

Results and Discussion

Results of the attempts to acclimate *T. confusum* are presented in Table I. Each temperature regime produced significant differences in the factors recorded in the F_1 generation except in the dry weight comparison between 37°C and the control. Development of the parents (F_1) at the lower temperature resulted in a significant increase in the number of progeny. This increase was significantly higher than for those reared continuously at 37°C. However, the progeny of the insects moved to 37°C from 22°C were significantly smaller than their parents, but larger than those reared continuously at 37°C. There appears to be an acclimation in this strain when reared at the cooler temperature before exposure to the higher temperature. There is very little acclimation to the low temperature resulting from the rearing of the prior generation at the higher temperature.

Results of the attempts to effect an acclimation of the malathion resistant strain of *T. castaneum* are presented in Table II. Again we note that there are significant differences in the F_1 between the control and test temperatures except for the dry weight comparison between the control and 22°C. In these data we find an acclimation to 37°C in the progeny of the F_1 reared at 22°C. The data on length of development showed a significant shortening of the developmental time at 37°C when the adults were reared at the lower temperature. No significant difference was noted for weight.

Results of the attempts to effect an acclimation of the malathion susceptible strain of *T. castaneum* show that rearing of the previous generation at the low temperature did not provide any acclimation to the high temperature in the F_2 (Table III). The data showed the reverse to be true and that a significant reduction in the number of progeny occurred compared to that observed for those reared continuously at the higher temperature. Examining the data on the length of development, it is seen that there is quite a different situation. Here we find that rearing of the F_1 generation at the higher temperature gave an acclimation to the F_2 reared at the low temperature. This effect, a reduction in developmental time, was significant and reduced the time by one-half. Slight but significant differences in weight are seen for temperature changes in both directions.

When these data are viewed in the context of the storage plan of the BARD on arid and semiarid sites they take on added meaning. The BARD program called for rather rapid changes of the grain mass twice each year using forced ventilation to cool the grain during the winter nights and to heat it during the summer days. The data presented here suggest that if sublethal high temperatures or low temperatures which do not result in complete inactivity are achieved instead of lethal or inactivating temperatures, this could result in increased population numbers of these pest species and/or strains in the storage.

Table I. Results of suboptimal temperature effects (acclimation attempt) on a malathion susceptible strain of Tribolium confusum to 37°C and 22°C. (Average of 5 replications, each initiated with 200 unsexed adults)

	GENERATION	TEMPERATURE		
		37°C	27°C	22°C
NUMBER OF ADULT PROGENY	P_1		600	
	F_1	1698 d	2572 f	1013 c
	F_2	275 a		563 b
	F_2	1991 e		59 a
LENGTH OF DEVELOPMENT (DAYS)	F_1	38.2 c	36.6 b	74.2 f
	F_2	26.2 a		58.6 d
	F_2	38.0 c		63.4 e
DRY WEIGHT OF 200 ADULTS (g)	F_1	0.23 c	0.23 c	0.24 d
	F_2	0.21 a		0.22 b
	F_2	0.22 b		0.22 b

Means in factor rows followed by the same letter are not significantly different (Duncan's MRT P = 0.01%)

Table II. Results of suboptimal temperature effects (acclimation attempt) on a malathion resistant strain of *Tribolium castaneum* to 37°C and 22°C. (Average of 5 replications, each initiated with 200 unsexed adults)

	GENERATION	TEMPERATURE		
		37°C	27°C	22°C
NUMBER OF ADULT PROGENY	P_1		600	
	F_1	4180 f	2399 d	1034 b
	F_2	1997 c		1305 b
	F_2	3222 e		493 a
LENGTH OF DEVELOPMENT (DAYS)	F_1	22.0 b	30.4 d	77.2 g
	F_2	24.4 c		60.8 e
	F_2	20.0 a		73.6 f
DRY WEIGHT OF 200 ADULTS (g)	F_1	0.176 ab	0.167 a	0.183 b
	F_2	0.174 ab		0.168 a
	F_2	0.167 a		0.180 b

Means in factor rows followed by the same letter are not significantly different (Duncan's MRT P = 0.01%)

Table III. Results of suboptimal temperature effects (acclimation attempt) on a malathion susceptible strain of *Tribolium castaneum* to 37°C and 22°C. (Average of 5 replications, each initiated with 200 unsexed adults)

	GENERATION	TEMPERATURE		
		37°C	27°C	22°C
NUMBER OF ADULT PROGENY	P_1		600	
	F_1	4951 d	4134 c	398 a
	F_2	3384 c		504 a
	F_2	2060 b		594 a
LENGTH OF DEVELOPMENT (DAYS)	F_1	31.6 d	26.8 b	78.4 f
	F_2	20.6 a		57.6 e
	F_2	20.0 a		28.8 c
DRY WEIGHT OF 200 ADULTS (g)	F_1	0.244 b	0.243 b	0.247 b
	F_2	0.225 a		0.244 b
	F_2	0.245 b		0.221 a

Means in factor rows followed by the same letter are not significantly different (Duncan's MRT P = 0.01%)

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