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INFLUENCE OF THERMAL ACCLIMATION ON THE SURVIVAL OF *SITOPHILUS GRANARIUS* (L.) AND *ORYZAEPHILUS SURINAMENSIS* (L.) AT LOW TEMPERATURES

by

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ABSTRACT

Low temperatures have been used for many years to control populations of stored-product insects. The aim of aeration was primarily to cool down the grain and then to prevent its deterioration by reducing the number of insects. In Belgium, the mild winters enable insects to survive to the next season. In autumn, the progressive lowering of temperature has an acclimation effect on stored-product insects.
The present study was undertaken to determine the survival at low temperatures of non cold-acclimated and laboratory- and field-cold-acclimated insects. We have chosen to work with the granary weevil *Sitophilus granarius* (L.) and the saw-toothed grain beetle *Oryzaephilus surinamensis* (L.). They are the most frequent stored-grain pests in Belgium.
To compare the cold-hardiness of different laboratory cold-acclimated insects, *S. granarius* and *O. surinamensis* were placed at nine different cold-acclimation temperature regimes. Insects were kept at 5°C for 2, 4 and 6 weeks or at −5°C for 4, 7 and 14 days. To assess the field-cold-acclimation in autumn and in winter, insects were monthly taken from a bin and transferred to 5°C for 6 weeks. *S. granarius* adults were more cold-hardy than *O. surinamensis*, but *O. surinamensis* adults compensated their cold-sensibility by a great ability to acclimate. *S. granarius* is able to survive the winter in Belgium because of its cold-hardiness while *O. surinamensis* survives because of its ability to acclimate to low temperatures.

KEY WORDS: Coleoptera, *Sitophilus granarius*, *Oryzaephilus surinamensis*, thermal acclimation, low temperatures.

INTRODUCTION

Low temperatures (aeration and refrigerated aeration) have been used for many years to control populations of stored-product insects (BURGES & BURRELL, 1964; BURRELL & LAUNDON, 1967; BURRELL, 1967; DONAHAYE *et al.*, 1973; HUNTER & TAYLOR, 1980). The aim of aeration is primarily to cool down the grain and to prevent its deterioration by reducing the number of insects, but not to eliminate the whole population. In Belgium, the mild winters and the gradual falling of temperature by aeration enable insects to survive to the next season. It is for this reason that the present study about the role of the acclimation of stored-product insects has been undertaken.

Physical methods of control such as aeration are indispensable to reduce the resistance to insecticides. Resistance increases the cost of chemical control and the quantity of pesticides in the environment. To evaluate the potential of using low temperatures as physical method of control, we have chosen to work with the granary weevil *Sitophilus granarius* (L.) (Coleoptera: Curculionidae) and the saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae). They are the most frequent pests of stored-grains in Belgium. LETELLIER *et al.* (1994) mentioned that these two species make up more than 70% of insects infesting bins and elevators in Belgian farms.

The present study was undertaken to assess the influence of thermal acclimation on the survival of adult *S. granarius* and *O. surinamensis* at low temperatures.

MATERIALS AND METHODS

Insect cultures

Cultures of *S. granarius* (strain Av2: Anvers-Belgium) and *O. surinamensis* (strain OPe: Perwez-Belgium) were established with initial densities of about 250 adults per 500 g of wheat grains and 65 g of rolled oats, respectively. Both species were reared at 27 ± 1°C and 60 ± 5% RH.

Low temperature mortality

Schedules of mortality were established at 0, 5 and 10°C for *S. granarius* and *O. surinamensis*. 50 non-cold-acclimated insects were placed in ventilated 300 ml jars containing 250 g of wheat for both species. Mortality under each temperature was determined at various times. For each observation there were four replicates. The sexes of the beetles were not determined.

Field cold acclimation

One bin containing 300 kg of wheat was infested in May 1994 by 4000 *S. granarius* and 4000 *O. surinamensis*. From October onwards, 200 *S. granarius* and 200 *O. surinamensis* were taken monthly and transferred to 5°C for 6 weeks. After this period, their mortality was observed.

TABLE I

Cold-acclimation temperature regimes tested on *Sitophilus granarius* and *Oryzaephilus surinamensis*.

Acclimation regimes	Temperature regimes
1.1	3 weeks at 25°C
1.2	3 weeks at 15°C
1.3	3 weeks at 10°C
1.4	1 week at 20°C, 1 week at 15°C and 1 week at 10°C
2.1	6 weeks at 25°C
2.2	6 weeks at 15°C
2.3	6 weeks at 10°C
2.4	3 weeks at 15°C and 3 weeks at 10°C
3.1	1 week at 20°C, 3 weeks at 15°C and 3 weeks at 10°C

Laboratory cold acclimation

To compare the cold-hardiness of different cold-acclimated insects, *S. granarius* and *O. surinamensis* were placed at nine different cold-acclimation temperature regimes (Table I). Insects were kept at 5°C for 2, 4 and 6 weeks or at −5°C for 4, 7 and 14 days.

For each cold-acclimation temperature regime, 600 beetles of each species, in twelve groups of 50, were held in ventilated 300 ml jars of wheat. After acclimation and transfer to 5°C (2, 4 and 6 weeks) or −5°C (4, 7 and 14 days), the jars were placed at 30°C for 24 hours and the mortality was observed in 200 beetles.

RESULTS

Low temperature mortality

In grain cooled at 10°C, about 90% of the beetles of both species survived after 13 weeks (Figs 1 and 2). More than 90% of *S. granarius* were still alive after 17 weeks. The mortality rates at this temperature were very low. Mortality rates were much higher at 5 and 0°C. Adult *O. surinamensis* were more sensitive to low temperatures than *S. granarius*. At 0°C, no adult survived 2 weeks for *O. surinamensis*, and 6 weeks for *S. granarius*. More granary weevils than saw-toothed grain beetles survived after 5 weeks at 5°C.

Field cold acclimation

The percentages of dead *S. granarius* and *O. surinamensis* at 5°C after 6 weeks are shown in Fig. 3. There was no difference between the mortality of both species during the October-December period. After this period, the

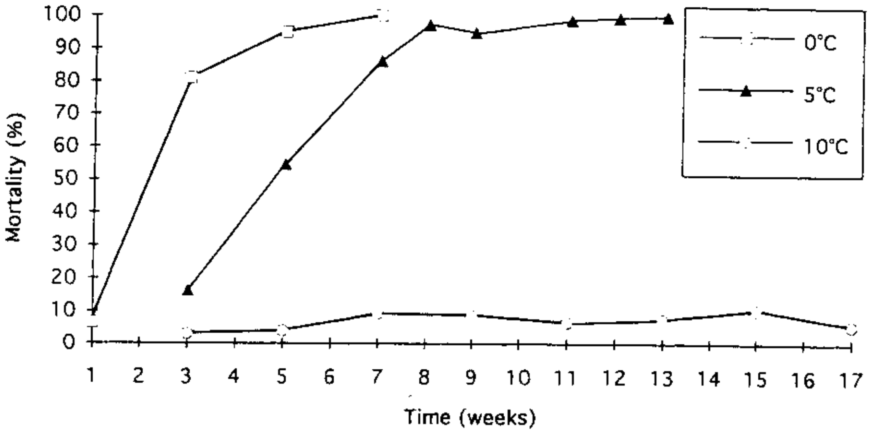

Fig. 1. The mortality of *Sitophilus granarius* at 0, 5 and 10°C.

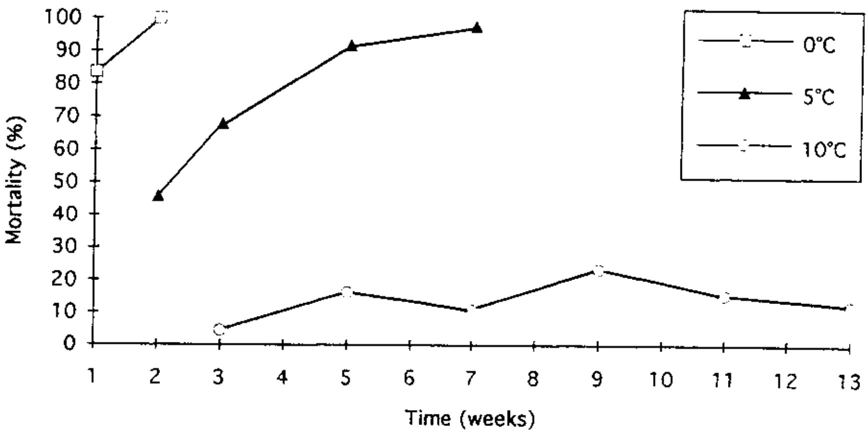

Fig. 2. The mortality of *Oryzaephilus surinamensis* at 0, 5 and 10°C.

mortality rates of adult *O. surinamensis* progressively decreased. There was no lowering in the mortality rates of *S. granarius* before march 1995. From this period onwards, mortality rates of both species progressively increased up to the maximum. These observations result from acclimation occuring in *O. surinamensis* from January to April.

Laboratory cold acclimation

Figure 4 indicates a significant reduction in mortality of *S. granarius* after the 3.1-cold-acclimation temperature regime. After one week at 20°C, three

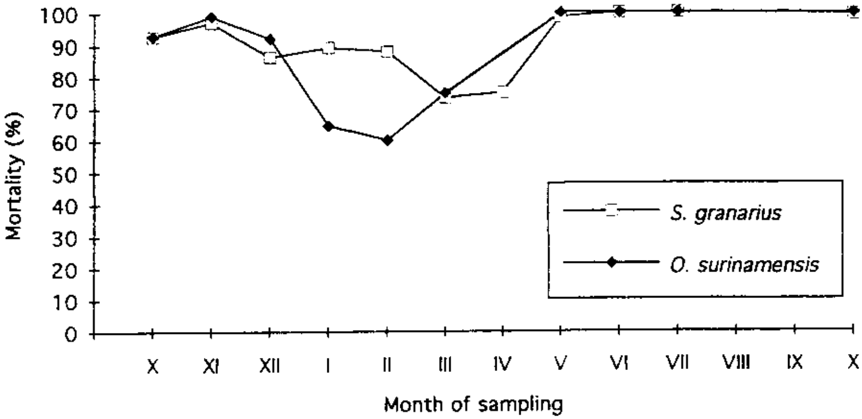

Fig. 3. The mortality of *Sitophilus granarius* and *Oryzaephilus surinamensis* acclimated to cold in a 300-kg bin of wheat and transferred to 5°C for 6 weeks.

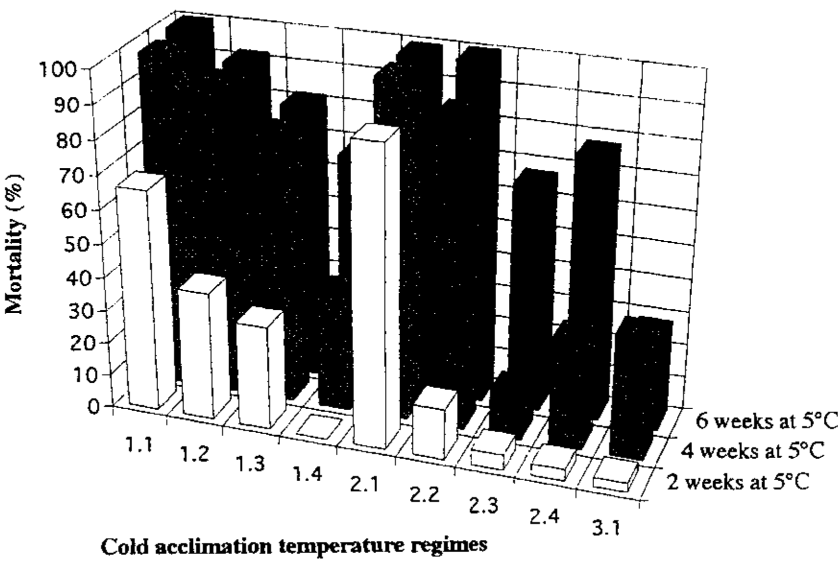

Fig. 4. The mortality of laboratory-cold-acclimated *Sitophilus granarius* exposed at 5°C for 2, 4 and 6 weeks.

weeks at 15°C and three weeks at 10°C, the ability of adults to survive exposure to 5°C was greatly increased (about 30% mortality after 6 weeks). For the 1.1- and 2.1-regimes, no adult survived a 6 weeks of exposure to 5°C. Those regimes were considered as non-acclimated samples (control).

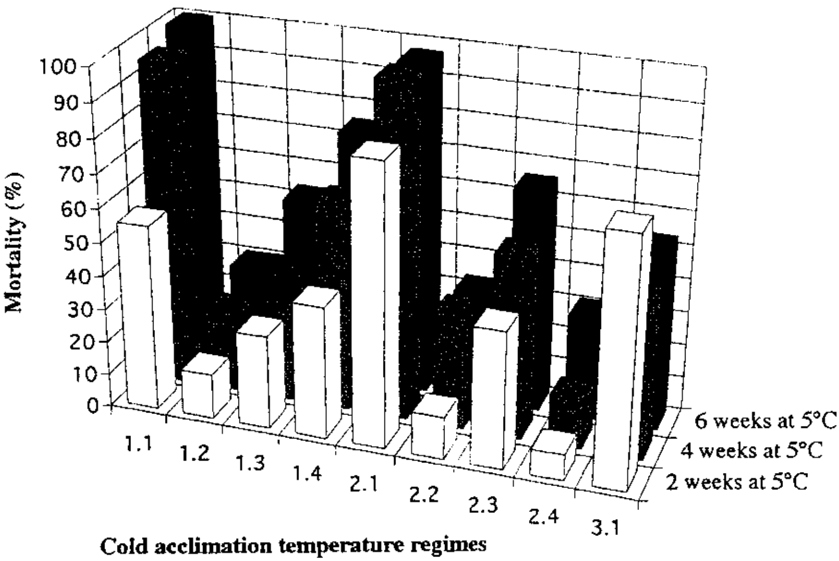

Fig. 5. The mortality of laboratory-cold-acclimated *Oryzaephilus surinamensis* exposed at 5°C for 2, 4 and 6 weeks.

Figure 5 shows that various acclimation regimes (1.2-, 1.3-, 2.2- and 2.4-regimes) allowed for acclimating of *O. surinamensis* (about 30% mortality after 6 weeks' exposure to 5°C).

The results given in Fig. 6 show that acclimation of adult *S. granarius* makes it more cold-hardy than non-cold-acclimated insects (1.1- and 2.1-control temperature regimes: 100% mortality). There is no difference between the seven other cold-acclimation temperature regimes (around 58% mortality). In contrast, for *O. surinamensis*, only the 2.4-acclimation regime permitted acclimation of adults. In fact, in order to really test the effect of acclimation on the mortality at −5°C, we must observe the mortality after a 4 days' exposure. After this period, mortality rates observed after the 1.1- and 2.1-control temperature regimes were respectively 100% and 96.5%. In contrast, the mortality rates were very low in 4 acclimation regimes (1.2, 1.4, 2.2 and 2.4). The same results were found after a 7 days' exposure to −5°C.

DISCUSSION

Cold-hardiness in insects is affected by many factors. One of the most important is the degree of cold-acclimation (FIELDS, 1990). Lethal temperature varies considerably and depends on the species, stage of development,

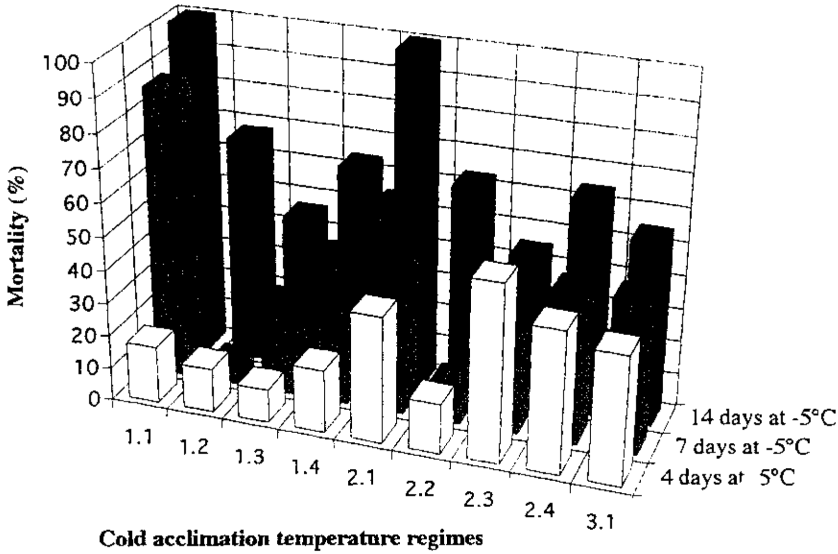

Fig. 6. The mortality of laboratory-cold-acclimated *Sitophilus granarius* exposed at −5°C for 4, 7 and 14 days.

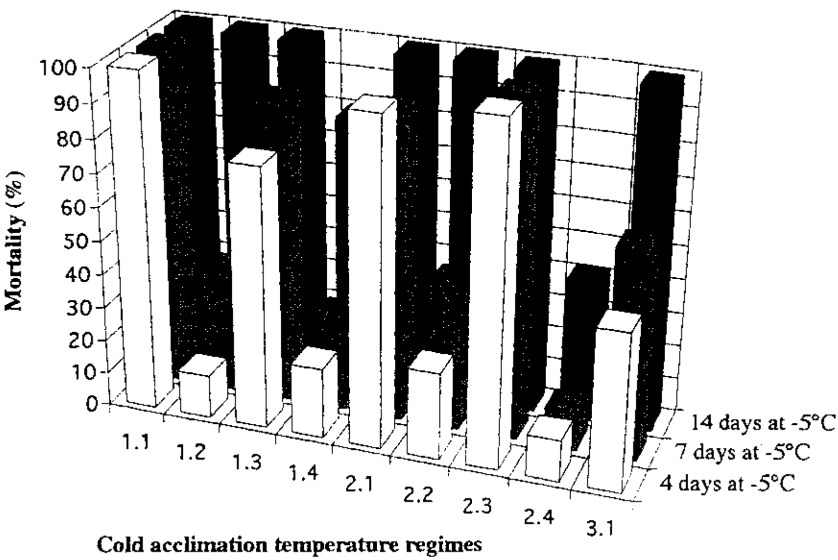

Fig. 7. The mortality of laboratory-cold-acclimated *Oryzaephilus surinamensis* exposed at −5°C for 4, 7 and 14 days.

acclimation and relative humidity (EVANS, 1983; FIELDS, 1992). In the first experiment, survival at low temperatures differed between species, being shortest in *O. surinamensis* and longest in *S. granarius*. This is in agreement with the observations of EVANS (1983) but contradicts the results of ARMITAGE & LLEWELLIN (1987). This contradiction may be ascribed to the strain of insects. Survival at low temperatures differed, sometimes considerably, between non-cold-acclimated insects and cold-acclimated insects. The temperature of 15°C appears very important in the acclimation process. This temperature was used successfully by different authors (EVANS, 1981; SMITH, 1970; OHTSU *et al.*, 1993; FIELDS, 1993).

The lowering of mortality rates reported earlier (in laboratory- and field-acclimations) indicated that exposure to gradually falling temperatures increased the cold-tolerance of both species. The manifestation of the increased cold-tolerance in terms of survival was studied by comparing the survival at 5°C of insects cooled gradually to that temperature (laboratory- and field-acclimations) with the survival of insects transferred from 25°C to 5°C. The increased cold tolerance was also studied in the laboratory by comparing the survival at −5°C between both cold-acclimated species. At 5°C, only one cold-acclimation temperature regime (3.1) increased survival of *S. granarius*. On the other hand, 4 acclimation regimes showed a significant decrease in mortality of *O. surinamensis*. This species is more able to acclimate than *S. granarius*. This confirms the observations from the experimental bin: mortality at 5°C decreased from around 90% to 60% for cold-acclimated *O. surinamensis* and stayed over 75% for cold-acclimated *S. granarius*. However, the effect of acclimation on mortality of *O. surinamensis* at −5°C was observed only after the 2.4-cold-acclimation temperature regime (3 weeks at 15°C and 3 weeks at 10°C), which decreased mortality from 100% to 40%. The observations on *O. surinamensis* after 4 and 7 days' exposures at −5°C showed the importance of acclimation temperatures near to 15°C. Surprisingly, all cold-acclimation temperature regimes showed acclimation of adult *S. granarius* and tolerance to negative temperatures. On the one hand, acclimation in *O. surinamensis* leads to tolerance for positive-cold temperatures. On the other hand, *S. granarius* are more able than *O. surinamensis* to acclimate to negative temperatures. In Belgium, it is very exceptional to obtain the temperature of −5°C in the middle of a bin of wheat. Considering both species, *S. granarius* is able to survive the winter because of its cold-hardiness, and *O. surinamensis* because of its ability to acclimate to positive-cold temperatures.

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