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EFFECT OF TEMPERATURE ON *CALLOSOBRUCHUS CHINENSIS* (BRUCHIDAE : COLEOPTERA) REARED ON DIFFERENT STORED PRODUCTS

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Abstract: *Callosobruchus chinensis* was reared on *Vigna radiata* (green gram), *Lence esculentum* (Lentils) and *Cicer arietinum* (chickpea). Longevity, fecundity and hatchability of eggs of this pest were studied at different temperatures (30°C, 32°C, 34°C, 38°C, 42°C and 46°C) when reared on these stored grains. Fecundity and longevity were found to be significantly less at higher temperatures. Each female laid about 94 eggs at 30°C and only 21 eggs at 46°C on *V. radiata*. On *L. esculentum*, 98 eggs were laid by a single female at 32°C but only 20 eggs at 46°C. While on chickpea 72 and 22 eggs were laid at 32°C and 46°C respectively. The longevity decreased from 7.6 days at 30°C to 3.3 days at 46°C on *Vigna radiata*, from 7 days at 30°C to 3.3 days at 46°C on *Lence esculentum* and on *Cicer arietinum* from 6.3 days to 3.6 days at 30°C and 46°C, respectively. Maximum eggs were laid on *L. esculentum* at 32°C and on *Vigna radiata* at 30°C, but hatching was maximum on *V. radiata* (84%) at 32°C. Almost no eggs hatched at 38°C and above, 54°C was found to be the lethal temperature as the insects died within 20 minutes at this temperature.

Key words: Temperature, whole grains, pulses.

INTRODUCTION

Each insect species can exist only in a specifically limited range of ambient temperature, relative humidity, radiation and other physical factors of the environment. They are to a great extent temperature oriented (Wigglesworth, 1953) and utilize radiant energy from the sun as a source of heat (Duspiva and Cerny, 1928). Insects show various adaptations to control their body temperature as has been shown for various insects belonging to different orders like Orthoptera, Lepidoptera and Hymenoptera (Fraenkel, 1929; Rucker, 1934).

In nature insects may rest in spots cooled by evaporation, and are thus able to exist in environments far above lethal temperature (Mellanby, 1933). But this ability exists only in insects above a certain size. As the insect becomes smaller the volume to surface ratio decreases, and it can lower its body temperature only by evaporating more of its

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body water that it could affort to lose (Mellanby, 1932). This emphasizes the importance of temperature in the life history of the insects.

Temperature affects the birth and death rates, thus the density of insects in a given population will be in the measure a reflection of its thermal history. The effect of temperature on the birth rate of insects may be considered under two main headings: its effect on the rate of egg deposition in reproducing adults; and its effect on the developmental stages, the time required for hatching and completion of metamorphosis (Bursell, 1974a; Kakuda *et al.*, 1990).

Insect tissue tolerance to different temperatures vary considerably from one species to another (Deal, 1941). Death probably results from denaturation of proteins and in balance of some metabolic processes leading to the accumulation of some toxic products more rapidly than they could be removed (Hopf, 1940; Larsen, 1943; Bursell, 1974a). Some point between the limits of tolerance range is described as the optimum temperature (Nieschulz, 1933; Uvarov, 1931), at which the greatest percentage of individuals complete their development, or the shortest time at which the development is completed (Blunck, 1914; Galliard, 1935).

Reproduction is adversely affected by temperature more readily than any other physiological functions, and the range of temperatures over which it will occur is correspondingly limited (Bursell, 1974a). The exact nature and the extent of the range varies from species to species and either sex may suffer ill effects. Tobacco budworm, *Heliothis virescens* will not mate or oviposit at a temperature of 10°C while the maximum egg deposition occurs at 21°C and 27°C (Henneberry and Clayton, 1991). In cotton tipworm, *Crocidosema plebejana* 28°C is the optimum temperature. At 34°C its development rate and survival rates were found to be greatly reduced and all eggs laid were non-viable (Graeme and Zalucki, 1991). In *Kiefferulus barbitarsis* also the fecundity and the hatchability rates become accelerated from 25°C to 30°C (Palavesam and Muthukrishan, 1992). Duration of the oviposition period is also affected beyond the optimum temperature (Bursell, 1974a). These few examples demonstrate the critical nature of the process of reproduction when compared with other physiological processes.

Like other insects, insects of stored grains have certain temperature, moisture and food requirements which directly effect their abundance. It is a characteristic of most of them that their generations are short, rate of reproduction is high and individuals are long lived. Within certain limits their rate of development and reproduction of increases with rising temperature causing serve damage to stored grain (Cotton, 1963). Changes in temperature or humidity (Metcalf and Flint, 1967) or exposure to radiant energy (Murdock and Shade, 1991; Begum *et al.*, 1991) are the effective physical measure to destroy pests of stored grains. Exposure to high temperatures have been found to be effective in causing sterility (Saxena *et al.*, 1992). Most insects including those which attack stored grains and their developmental stages, are killed within three hours of exposure to temperature ranging from 125°F to 130°F (Metcalf and Flint, 1967; Hand and An, 1990). Temperature also affects the rate of oviposition, hatching and the rate at which they reach maturity.

Rates of oviposition are sometimes sensitive to changes in humidity. At low humidities egg laying is depressed. At higher humidities there is a sharp drop in the rate of oviposition. The preferred humidity varies from species to species. Some species prefer the saturated end of the humidity gradient e.g., larvae of *Agriotes*. Some prefer intermediate humidities like *Drosophila* and *Schistocerca*. The pests of stored products prefer relatively dry air (Bursell, 1974b; Willis and Roth, 1950).

Humidity also influences the survival of insect mainly through its effect on the water content of the body (Bursell, 1974b; Koidsumi, 1934). It also helps the insect to resist high temperature (Necheles, 1924; Mellanby, 1932; Cotton, 1963; Bursell, 1974b).

The present work was undertaken to study the effect of rising temperature accompanied by a more or less constant range of humidity on *Callosobruchus chinensis*, because it is advisable to control these insects by changing their ecological conditions rather than using insecticides.

MATERIALS AND METHODS

Collection and maintenance of beetles

The whole grain pulses infested with *Callosobruchus chinensis* were obtained from different local sources i.e., utility stores and other general stores. The infested grains were brought to the laboratory and placed in 6"x3" glass jars. The adults emerging from these grains were transferred to fresh glass jars filled 2/3 with different pulses.

Ten to fifteen pairs of insects were placed in each of them for egg laying. The jars were covered with a muslin cloth. All control rearing and maintenance was carried on at a temperature of 30°C and 60-70% relative humidity. The jars were checked daily to observe egg laying and also to remove any dead individuals. Eventually only grains bearing eggs were left in them.

Grains used: *Vigna radiata* (green gram), *Lence esculentum* (Lentils), *Cicer arietinum* (chickpeas).

Experimental set-up

Culture bottles 4"x3/4" were filled each with 5 gm of three different types of pulses. A newly emerged pair (a male and a female) was placed in each of them. Three replicates of each of the three different whole grains were then kept at different temperatures.

Experimental conditions

The insects were kept at 30°C, 32°C, 34°C, 38°C, 42°C and 46°C. The required temperatures were maintained by means of electric bulbs hung in wodden cabinets, in ovens and in incubators water-soaked cotton plugs for the culture bottles and petri dishes containing water were kept in ovens, cabinets and incubators to maintain the required range of humidity. Three replicates at each temperature were maintained. The number of eggs laid by each pair at different temperatures were counted after every 48 hours till death and a record was kept. Then the infested grains were trnasferred to a temperature of 30°C and 60-70% relative humidity. Hatching percentage was noted for insects maintained on different grains at each temperature.

Temperature was also increased to observe the thermal death point. All the glassware used was sterilized at 70°C to 80°C for 5 to 8 hours in an oven.

RESULTS

Mean of three replicates was taken for calculating fecundity, longevity and percentage hatch for insects reared on *Vigna radiata, Lence esculentum* and *Cicer arietinum* at different temperatures. The results are given below:

Temperature 30°C (Tables I-III)

Vigna radiata

Newly emerged pairs of *C. chinensis* (a male and a female) remained alive for about 7.6 days and during this period the female laid a total of 94 eggs. The eggs deposited by a single pair were kept separately to observe hatching. Out of 94 eggs laid by a single pair 38% hatched. They were kept for 24 days to observe whether they hatched or not.

Lence esculentum

Each pair lived for about 7 days and during this period the female laid 66 eggs out of which 41% hatched.

Cicer arietinum

Each pair lived for about 6.3 days and during this period the number of eggs laid by a single female was 62 out of which 44% hatched.

The longevity and number of eggs laid on *V. radiata* was found to be significantly higher than on *L. esculentum* or *C. arietinum*.

Table I: The number of eggs deposited at different temperature on different grains by a single pair of *Callosobruchus chinensis* till death (mean of 3 replicates).

Types of pulses	Mean number of eggs laid at different temperature						
	30°C	32°C	34°C	38°C	42°C	46°C	Total No. of eggs
Vigna radiata	94 ±5.96	82 ±9.27	80 ±5.78	41 ±10.59	26 ±2.9	21 ±0.57	344
Lence esculentum	66 ±4.04	98 ±1.15	72 ±3.75	45 ±7.5	18 ±1.73	20 ±1.44	319
Cicer arietinum	62 ±1.96	75 ±2.17	62 ±0.28	57 ±10.7	20 ±0.57	22 ±0.28	298

L.S.D. for temperature = 13.6; L.S.D. for grain = 15.61.

Temperature 32°C

V. radiata

Each pair lived for about 7 days and during this period the female laid 82 eggs out of which 84% hatched.

L. esculentum

Each pair lived for about 6.6 days and during this period they laid 98 eggs out of which 48% hatched.

C. arietinum

Each pair lived for about 6 days on this grain and during this period 75 eggs were laid by a single female out of which only 14% hatched.

Fecundity on *L. esculentum* was significantly higher at this temperature while longevity was significantly lower on *V. radiata* only. Significant difference was observed in longevity on *V. radiata* and on *C. arietinum* when compared to 30°C.

Table II: **Longevity of *Callosobruchus chinensis* at different temperatures on diffe pulses (mean of 3 replicates).**

Types of pulses	Mean longevity at different temperatures					
	30°C	32°C	34°C	38°C	42°C	46°C
Vigna radiata	7.6d ±0.0	7d ±0.28	6.3d ±0.57	5.3d ±0.0	6.6d ±0.28	3.3d ±0.0
Lence esculentum	7d ±0.28	6.6d ±0.0	6d ±0.28	5.6d ±0.28	6.3d ±0.28	3.3d ±0.0
Cicer arietinum	6.3d ±0.28	6d ±0.0	5.3d ±0.0	5d ±0.57	6.3d ±0.0	3.6d ±0.28

L.S.D. for temperature = 0.420; L.S.D. for grains = 0.59.

Temperature 34°C

V. radiata

Each pair lived for about 6.3 days and during this period the female laid 80 eggs out of which 56% hatched.

L. esculentum

Each pair lived for about 6 days and during this period 72 eggs were laid but only 29% hatched.

C. arietinum

Each pair lived for about 5.3 days and during this period the female laid 62 eggs while less than 1% hatched.

Fecundity was significantly lower *V. radiata* only. However, longevity was significantly lower on all grains. Significant difference was observed in fecundity on green gram and chickpeas. Longevity was significantly higher on *V. radiata* than on *C. arietinum*.

Table III: Percentage of egg hatched at different temperatures on different pulses during 24 days.

Types of pulses	Percentage of eggs hatched at different temperatures					
	30°C	32°C	34°C	.38°C	42°C	46°C
Vigna radiata	38	84	56	0.05	N.H	N.H.
Lence esculentum	41	48	29	N.H	N.H	N.H
Cicer arietinum	44	14	0.008	N.H	N.H	N.H

N.H = No hatching

Temperature 38°C

V. radiata

Each pair lived for about 5.3 days and during this period the female laid 41 eggs out of which less than 1% hatched.

L. esculentum

Each pair lived for about 5.6 days and 45 eggs were laid at this temperature by a single female but no egg hatched at this temperature.

C. arietinum

At this temperature the female lived for five days and 57 eggs were laid per female out of which none hatched.

Both fecundity and longevity were significantly lower at this temperature, but significantly higher on chickpeas than on green gram. Longevity was significantly higher on *L. esculentum* than on *C. arietinum* at this temperature.

Temperature 42°C

V. radiata

Each pair lived for about 6.6 days and during this period each female laid about 26 eggs out of which none hatched.

L. esculentum

Each pair lived for 6.3 days and during this period the number of eggs laid by a single female was 18. No hatching was observed.

C. arietinum

Each pair lived for about 6.3 days and during this period each female laid about 20 eggs but no hatching was observed.

Longevity were significantly higher at 42°C than at 34°C and 38°C. No significant difference was observed between fecundity and longevity on different grain at this temperature.

Temperature 46°C

V. radiata

Each pair lived for about 3.3 days and during this period each female laid about 21 eggs which did not hatch.

L. esculentum

Each pair survived for about 3.3 days and during this period each female laid 20 eggs with no hatching.

C. arietinum

Each pair lived for about 3.6 days and each female laid 22 eggs with no hatching.

Significantly lower fecundity and longevity was observed at this temperature but without any significant difference on different grains.

Thermal death point

At 54°C all the insects died within 20 minutes.

DISCUSSION

Species of the genus *Callosobruchus* are the major damaging pests of stored legumes (Southgate, 1964; Giga and Smith, 1987). Two best known species are *C. chinensis* (L.) and *C. maculatus* (F.).

Major biological barriers to any of the *Callosobruchus* species becoming pests are temperature variations and the inability of the insects to attack the leguminous seeds available (Howe and Currie, 1964). Some stored legumers are not attacked by Bruchidae. They show discrimination at two levels. One is the host selection, this is sensory to a greater extent. Second is the ability to complete larval development on the preferred host (Hanzen, 1977). The present research work was carried on three different types of host leguminous seeds, *Vigna radiata* (green gram), *Lence esculentum* (lentils) and *Cicer arietinum* (chickpeas). It concerned two main aspects of evaluation (i) to make a comparative study of the ability of *C. chinensis* adults to lay eggs and survival on these three common food legumes, (ii) to examine the effect of temperature on the fecundity, longevity and hatchability of the insect under study.

Closer examination on different legumes has revealed that the legumes on which the beetle breed influence the number of eggs laid (El-Sawaf, 1956). The smooth coated *V. radiata* was found to be the preferred host for opiposition, then *L. esculentum* and lastly *C. arietinum*. Different workers have also shown that smooth coated seeds are preferred for oviposition (Giga and Smith, 1987; Singh *et al.*, 1977; Ahmad *et al.*, 1993; Parr *et al.*, 1996). The smoothness and the thickness can be an important factor which facilitates penetration into the seed by the newly hatched larvae. The attraction and repulsion by odours emitted by different chemical substances in the seeds have been given as reasons by other workers when considering egg deposition by stored grain pests (Nwanze and Horber, 1976; Giga and Smith, 1985). *Vigna radiata* has a smooth and a thinner coat when compared to others. It was also shown that at different temperature this beetle showed different preferences for different food legumes. The maximum eggs were laid on *V. radiata* seeds at 30°C while 32°C was found to be the optimum temperature for egg laying on *L. esculentum* and *C. arietinum*. It could be that at this temperature the maximum inducement, in the form of vapours, was present to deposit eggs. This odour in some way could act as a primer for the insects to mature and deposit their eggs. These seeds are rough coated containing volatile chemical having maximum evaporation at 32°C.

The other aspect that was studied concerned the effect of varying temperatures on the number of eggs laying, longevity and the rate of hatching of the eggs laid. The profound effect of temperature on living organisms is well known. Insects have evolved the means to maintain the internal temperature within tolerable limits despite wide fluctuations in the temperature of their surroundings. Literally hundreds of insect species have been tested in various temperature gradient and choice chambers (Herter, 1953; Thiele, 1977; Uvarov, 1977). The range of temperature at which the majority of individuals conduct their activities normally is defined as preferred temperature range (Bursell, 1974a). Temperature selection studies have revealed that when temperature increased above the preferred levels, profound effects on fecundity and longevity occurred. Kim and Choi (1987) have also shown that life span of *C. chinensis* decreased with increase in temperature, while the number of eggs decreased with the increase of temperature from 30°C to 32°C on *V. radiata*. On *L. esculentum* the maximum eggs were laid at 32°C, the same as on *C. arietinum*. The decrease in fecundity with increasing temperature has been reported by various other workers like Bursell (1974a), Graeme and Zalucki (1991) and many others.

During the present study longevity was found to be significantly affected by temperature. At 30°C and 32°C the overall mean survival limits were found to be 7-7.6 days on *V. radiata*. Whereas at 34°C, 38°C and 46°C the overall mean survival time was 5-6 days, 5-5.6 days and 3.3-3.6 days respectively on this pulse. Although longevity was found to be different on different host seeds with varying temperature the trend was the same as found for *V. radiata*. It has also been reported by Yoshio (1990) that life expectation within a viable range is affected by temperature. The increase in temperature accelerates rate of metabolism thus decreasing the food reserves at a faster rate (Bursell, 1974a). At 42°C the longevity of the adults showed deviation from the usual pattern of behaviour i.e., the reduced longevity towards high temperatures had been replaced by increased duration of survival.

However, the egg laying behaviour remained almost the same. This unusual behaviour at 42°C is perhaps due to the triggering of some defence mechanism. Hence more energy is spent for increasing the survival limits than on reproduction. 54°C seemed to be the lethal temperature as 100% mortality occurred within 20 minutes at this temperature. These experiments show that like other insects this beetle also has a fairly well defined range of temperature within which it remains viable. The excessive heating causes too much evaporation leading to dessication and also resulting in denaturation of enzymes, thus disrupting the life processes which sooner or later cause death.

Reproduction and development take place within a fairly narrow range of temperature. Reproduction is adversely affected by temperature than any other physiological function and the range of temperature over which it occurs is correspondingly limited. The exact nature and extent of the range varies from species to species and either sex might suffer ill effects (Bursell, 1974a; Arlian, 1990). In the present study the preferred temperature was found to be 30±2°C. At 32°C maximum number of eggs were laid by *C. chinensis* on *L. esculentum* and minimum also on the same pulse at 46°C. This seemed to be the preferred substratum as far as the egg deposition was conserved, although survival was longest on *V. radiata*.

The eggs laid on *V. radiata* and *L. esculentum* showed maximum hatching of 84% and 48% respectively at 32°C, while in the eggs laid on *C. arietinum* the maximum hatching occurred at 30°C (44%). Thus optimal temperatures for survival are usually lower than those which permit faster development. The eggs laid at 34°C showed less percentage hatch on all grains up to the end of the experimental time. These observations indicate that development occurred at a faster rate on *V. radiata* with maximum hatching as compared to other legumes used in the experiment. Thus it was found to be the most susceptible to attack by *C. chinensis*, as has also been shown by previous workers like Giga and Smith (1987). Another point which needing attention is humidity. Temperature selection may be affected by humidity or state of hydration of the insects (Chapman, 1965; Thomson, 1970; Thiele, 1977). They can together effect fecundity and longevity markedly. Development and growth of insects like any other organisms is highly temperature and humidity dependent. In the present study the relative humidity was kept constant to avoid any discrepancy in the results. So, on the whole, it can be concluded that by increasing the temperature sufficiently an effective control can be achieved against this grain pest.

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