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Effect of Thermal Stress on Reproduction of Angoumios Grain Moth

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Abstract: *The Angoumois wheat moth (AGM) causes significant loss of grain stored in stores and fights for years. This insect is a major pest of stored grains because its immature stage (caterpillars) develop entirely in the grain core. The attacked kernels are mostly hollow with round holes where the moths emerge. It will weigh about 20% less than the sound kernel. AGM -attacked cereals usually have an unpleasant odor that refuses to eat them or limits their use by humans and animals. So to control these insects different temperatures are used. In this study five different temperatures (15 ºC, 20 ºC, 25 ºC, 30 ºC and 35 ºC) were used to control Angoumois seed moths under maternity conditions. Results revealed that a maximum incubation period of Sitotroga cereallea eggs was observed on 15 ºC temperature (6.34±0.13) and 20 ºCtemperatures (6.01±0.78). While a minimum incubation period of Sitotroga cereallea eggs was observed on 30 ºCtemperature (3.02±0.65). A maximum hatching % of eggs Sitotroga cereallea was observed in 25 ºC temperature (91.47±1.02). While a minimum hatching % of eggs Sitotroga cereallea was observed in 15ºCtemperature (70.34±0.13). A maximum larval mortality of Angoumois grain moth, Sitotroga cereallea was observed on 15 ºCtemperature (33.34±0.13). While a minimum larval mortality of Sitotroga cereallea was observed on 30 ºC temperature (11.02±0.65). A maximum larval development period of Sitotroga cereallea was observed on 15 ºC temperature (23.34±0.13) and 20 ºC temperature (22.01±0.78). While a minimum larval development period of Sitotroga cereallea was observed in 30 ºC temperature (16.02±0.65). A maximum adult emergence (%) of Sitotroga cereallea was observed on 30 ºCtemperature regime (91.02±0.6). While a minimum adult's emergence percent of Sitotroga cereallea was observed on 15 ºC (69.34±0.13). A maximum pupal period of Sitotroga cereallea was observed on 15 ºC(7.34±1.02). While minimum pupal period of Sitotroga cereallea was observed on 30 ºC(4.02±0.65). A maximum fecundity of Sitotroga*. Cerealella *was observed on 30 ºCtemperature (272.02±0.65), while a minimum of Sitotroga cereallea was observed in 15 ºCtemperature (185.34±0.13). A maximum oviposition rate of Sitotroga cereallea was observed on 30 ºCtemperature (17.65±0.65) and 25 ºCtemperature (17.03±1.02). While a minimum oviposition rate of Sitotroga cereallea was observed on 35 ºCtemperature (13.97±0.56). A maximum male and female adults longevity of Sitotroga cereallea was observed on 30 ºCtemperature (15.41±0.65 female, 12.44±0.81 male) and 35 ºCtemperature (15.24±0.56 female, 12.34±0.65 male). While a minimum male and female adults longevity of Sitotroga cereallea was observed on 15 ºCtemperature (11.34±0.13 female, 9.14±0.23 male). We conclude that temperatures of 25 oC, 30 oC and 35 oC are the best temperatures for the rearing of Angoumois seed moth, Sitotroga cerealella, while temperatures of 15 oC and 20 oC are unsuitable temperatures for Angoumois seed moth, Sitotroga cerealella and 15 ºC and 20 ºC. The results indicate that both temperatures can be used in stored gowdown to control these insect pests.*

Keywords: effects, thermal stress, reproduction, angoumois grain moth

Introduction:

Temperature is one of the most influential environmental elements on insect physiology and behaviour (Ratte, 1985). According to response patterns, impacts on stability, and other unique features, the various manifestations of this influence can be loosely grouped into three groups. For starters, temperature has an impact on insect growth and development. Except at the top extremities, when the rate of decline and the response curve are markedly asymmetric (Brière et al., 1999; Ratte, 1985), this relationship is generally linear. A thermo period's pace of development is generally the same or slightly faster than at its average effective temperature (Ratte, 1985; Beck, 1983). Temperature has a comparable effect on the intensity of different behavioural and physiological processes (e.g., speed movement, immediate oviposition rate, etc.) and is generally quick and reversible, with intermittent temperatures generating similar variations in insect activity. Second, several metrics (lifetime fertility, survival rate etc.) reach a maximum at a certain optimal temperature, and symmetry declines more or less towards both the lower and higher tolerance limits, implying that the medium thermo period gives "better" outcomes than the average thermo period (Beck, 1983; Ratte, 1985). Third, temperature can operate as a primary regulator of seasonal or daily cycles, influencing several elements of insect life indirectly (Zaslavski, 1988; Tauber et al., 1986; Danks, 2003).

Sitotroga cerealella (Olivier) (Lepidoptera: Gelechiidae), the Angoumois grain moth, is a common pest of stored maize, *Zea mays L*., and other cereals across the world. Because moths are unable to penetrate deeper into the grain mass, damage to grains in bulk storage is often restricted to the top 23 cm (Shahjahan, 1975). Even so, *S. cerealella* can cause significant damage because, after oviposition outside the grain kernels, newly hatched larvae penetrate the kernels and continue their development inside the kernels, devouring a large portion of the kernels and depositing their faeces. The influences of temperature and humidity on *S.cerealella* strains that grow on stored corn have been described in various studies for distinct regional populations developing on different commodities, including for U.S. strains (Perez-Mendoza et al., 2004).
Sitotroga cerealella (Oliver) (Lepidoptera: Gelechiidae), the Angoumois cereal butterfly, is a prominent coloniser of grains kept in subtropical and temperately mild locations across the universe. The rice is Pakistan's significant cereal and chief food crop. Each year around 2.3 million people added to 120 million population of Pakistan, with singalling as enhancing demand for rice. Rice is the primary source of nutrition for about 90% population of Pakistan (Ayertey, 2015). Farmers preserve more than 65 percent of the entire rice produced for food, feed, and seed until the next season. Insect pests devastate numerous types of stored grains, especially rice, incurring significant economic losses.

The Angoumois grain moth is one of the most dangerous post-harvest pests among them. The tassels typically contain no indications of assault during harvest, and the first adults appear in storage a few weeks later. *Sitotroga cerealella*, a highly effective seed penetrator, has seriously harmed a considerable volume of waste rice held at farmer levels (Cogburn, 2015). One of the most common species in stored rice is the Angoumois grain moth, *Sitotroga cerealella*, often known as rice moth or rice moth (Hansenet al., 2014). It appears to be the principal and most common pest in rice-storage bags. It damages grain not just in storage, but also in the field, increasing its potential to deteriorate (Dhotmal and Dumbre 2012). Newly hatched caterpillars burrow immediately into the grain, where they normally stay to grow larvae and pupae. These bugs' tunnel larvae in the kernels inflict significant damage and render the grains more vulnerable to secondary insect problems (Hill, 2013). Before becoming pupae, the larvae create a small round transparent window behind the grain layer. Pupation occurs in a fragile cocoon. Adults fly well and cross-attacks are common, although they are short-lived, last only 5–12 days on average, and reproduction can occur year-round under adequate conditions (Hill, 2013).

Material Methods:
The experiment was conducted in the Laboratory of Entomology section of Agriculture Research Institute, Sariab Road Quetta. The culture of Angoumois grain moth, Sitotroga cerealella were reared on wheat grains under 25 Ċ ±2 with 65±5 % Relative humidity (RH), at room temperature. In present experiment five different temperatures treatments (15 ºC, 20ºC, 25 ºC, 30 ºC and 35ºC) was used as treatment to find out the different temperature effects on the life parameters and reproduction of Angoumois grain moth, Sitotroga cerealella. Each treatment was replicated three times.

1.1 Plan of Work

In the present experiment Plastic jar was used for insects rearing and covered with cotton yarn. Wheat was provided in whole experiment.

Figure .1

1.2 Eggs

Three hundred (300) eggs were collected in each treatment with three replications and exposed to different temperature (15 ºC, 20 ºC, 25 ºC, 30 ºC and 35ºC) for checking the hatching (%) percentage of Angoumois grain moth eggs and duration of hatching times.

Figure 2

1.3 Larvae

After hatching eggs two hundred (200) young larvae was collected from treated eggs in each treatment with three replications and released on different temperature (15 ºC, 20 ºC, 25 ºC, 30 ºC and 35ºC) to find the mortality (%) and larval developmental periods of Angoumois grain moth.

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Figure 3

1.4 Pupae

One hundred (100) one day old pupae was collected from treated larvae in each treatment with three replications and exposed on different temperature (15 ºC, 20ºC, 25 ºC, 30 ºC and 35ºC) to find the adult emergence (%), and pupal days of Angoumois grain moth.

Figure 4

1.5 Adults Longevity and reproduction

Fifty (50) one day old male and female adult's pair was collected from treated pupae after hatching % of adults and exposed to different temperature (15 ºC, 20 ºC, 25 ºC, 30 ºC and 35ºC) until the death of males and females adults. Female and male pair was released in single plastic cup and cover with Cotton net yarn and butter paper was used for eggs laid female. Cotton net yarn and butter paper was replaced on daily basis. Male and female reproduction and survival rates were recorded on a daily basis. The experiment was continued until the males and females death.

Figure 5

Result and discussions:

Table 4.1: Effect of different temperature regimes on egg incubation period of Angoumois grain moth, *Sitotroga cereallea*.

Treatments (ºC)	Egg Incubation period (Days)
15 ºC	6.34±0.13b
20 ºC	6.01±0.78b
25 ºC	5.47±1.02b
30 ºC	3.02±0.65a
35 ºC	4.24±0.56ab

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05)

A maximum incubation period of *Sitotroga cereallea* eggs was observed on 15ºC temperature (6.34±0.13), followed by 20ºC temperature (6.01±0.78), 25 ºC temperature (5.47±1.02) and 35ºC temperature (4.24±0.65), while a minimum incubation period of *Sitotroga cereallea* eggs was observed on 30ºC temperature (3.02±0.65). Statistically, significant difference was observed on 30ºC temperature when values were compared with 15ºC, 20ºC and 25ºC temperature. Whereas, statistically no significant difference was noticed among 15ºC, 20ºC, 25ºCand 35ºC temperature regimes. Table-1

Table 4.2: Effect of different temperature regimes on egg hatching (%) of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Egg hatching (%)
15 ºC	70.34±0.13c
20 ºC	71.01±0.78c
25 ºC	91.47±1.02a
30 ºC	81.02±0.65b
35 ºC	82.24±0.56b

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05)

A maximum hatching % of eggs *Sitotroga cereallea* was observed in 25ºC temperature (91.47±1.02), followed by 30ºC temperature (81.01±0.65), 35ºC temperature (782.24±0.56) and 20ºC temperature (71.01±0.78) , while a minimum hatching % of eggs *Sitotroga cereallea* was observed in 15ºC temperature (70.34±0.13). Statistically, significant difference was observed in 25ºC temperature when it is compared with 30ºC, 35ºC, 15ºC and 20ºC temperature. Whereas statistically no significant difference was noticed between 15ºC, and 20ºC. A similerly 30 ºC and 35ºC temperature regimes as indicated in Table-2.

Table 4.3: Effect of different temperature regimes on the larval mortality of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Larval mortality
15 ºC	33.34±0.13a
20 ºC	26.01±0.78b
25 ºC	20.47±1.02c
30 ºC	11.02±0.65e
35 ºC	14.24±0.56d

Values (mean ± SE) in given column letters are significantly different by Turkey test (p<0.05)

A maximum larval mortality of Angoumois grain moth, *Sitotroga cereallea* was observed on 15ºC temperature (33.34±0.13), followed by 20ºC temperature (26.01±0.78), 25ºC temperature (20.47±1.02) and 35ºC temperature (14.24±0.56), while a minimum larval mortality of *Sitotroga cereallea* was observed on 30ºC temperature (11.02±0.65). A statistically P<0.05 significant difference was observed in all given temperature regimes table-3.

Table 4.4: Effect of different temperature regimes on larval development period of Angoumois grain moth, *Sitotroga cerealella.*

Treatments (ºC)	Larval development periods
15 ºC	23.34±0.13a
20 ºC	22.01±0.78a
25 ºC	19.47±1.02b
30 ºC	16.02±0.65c
35 ºC	17.24±0.56c

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05)

A maximum larval development period of *Sitotroga cereallea* was observed on 15ºC temperature (23.34±0.13), followed by 20ºC temperature (22.01±0.78) , 25ºC temperature (19.47±1.02) and 35 ºC temperature (17.24±0.56) , while a minimum larval development period of *Sitotroga cereallea* was observed in 30ºC temperature (16.02±0.65). Statistically P<0.05 significant difference was observed on 25ºC temperature when it is compared with 15ºC, 20ºC, 30 ºC and 35ºC temperature. Whereas, statistically no significant difference was noticed between 15ºC and 20ºC similarly 30ºC and 30ºC temperature regimes as mentioned in Table-4.

Table 4.5: Effect of different temperature regimes on adult emergence (%) of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Adult emergence (%)
15 ºC	69.34±0.13e
20 ºC	75.01±0.78d
25 ºC	87.47±1.02b
30 ºC	91.02±0.65a
35 ºC	84.24±0.56c

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05)

A maximum adult emergence (%) of *Sitotroga cereallea* was observed on 30ºC temperature regime (91.02±0.6), followed by 25ºC (87.47±1.02), 35ºC (84.24±0.56) and 20ºC (75.01±0.78), while a minimum adult's emergence percent of *Sitotroga cereallea* was observed on 15ºC (69.34±0.13). Statistically, significant difference was observed among all given treatments temperature regimes as given in Table-5.

Table 4.6: Effect of different temperature regimes on pupal period of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Pupal period (Days)
15 ºC	7.34±0.13a
20 ºC	6.01±0.78b
25 ºC	5.47±1.02c
30 ºC	4.02±0.65c
35 ºC	5.24±0.56c

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05)

A maximum pupal period of *Sitotroga cereallea* was observed on 15ºC (7.34±1.02), followed by 20ºC (6.01±0.78), 25ºC (5.47±1.02) and 35ºC (5.24±0.56), while minimum pupal period of *Sitotroga cereallea* was observed on 30ºC (4.02±0.65). Statistically, significant difference was observed on 25ºC, 15ºC and 20 ºC. Whereas statistically no significant difference was noticed among 25ºC, 30ºC, and 35ºC temperature regimes as given in Table-6.

Table 4.7: Effect of different temperature regimes on the Fecundity of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Fecundity
15 ºC	185.34±0.13c
20 ºC	195.01±0.78e
25 ºC	246.47±1.02b
30 ºC	272.02±0.65a
35 ºC	213.24±0.56d

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05).

A maximum fecundity of *Sitotroga*. *Cerealella* was observed on 30ºC temperature (272.02±0.65), followed by 25 *Sitotroga* temperature (246.47±1.02) , 35ºC temperature (213.24±0.56) and 20ºC temperature (195.01±0.78) , while a minimum of *Sitotroga cereallea* was observed in 15ºC temperature (185.34±0.13). Statistically, significant difference was observed in all given treatments of temperature regimes as given Table-7.

Table 4.8: Effects of different temperate on Oviposition rate of *Sitotroga cerealella.*

Treatments ºC	Oviposition rates
15 ºC	**16.14±0.13a**
20 ºC	**16.28±0.78a**
25 ºC	**17.03±1.02a**
30 ºC	**17.65±0.65a**
35 ºC	**13.97±0.56b**

Values (mean ± SE) in given column letters are significantly different by Tukey test (p<0.05) A maximum oviposition rate of *Sitotroga cereallea* was observed on 30ºC temperature (17.65±0.65), followed by 25ºC temperature (17.03±1.02), 20ºC temperature (16.28±0.78) and 15 ºC temperature (16.14±0.13), while a minimum oviposition rate of *Sitotroga cereallea* was observed on 35ºC temperature (13.97±0.56). Statistically, significant difference was observed on 35 ºCtemperature when it was compared with 15ºC, 20ºC, 25 and 30ºC temperature. Whereas statistically no significant difference was noticed among 15ºC, 20ºC, 25 and 30ºC temperature as given in Table-8.

Table 4.9: Effect of different temperature regimes on adult's longevity of Angoumois grain moth, *Sitotroga cerealella*

Treatments (ºC)	Female longevity (Days)	Male longevity (Days)
15 ºC	**11.34±0.13b**	**8.14±0.23b**
20 ºC	**12.01±0.78b**	**9.31±0.03b**
25 ºC	**14.47±1.02a**	**11.04±0.27a**
30 ºC	**15.41±0.65a**	**12.44±0.81a**
35 ºC	**15.24±0.56a**	**12.34±0.65a**

Values (mean ± SE) in given column letters are significantly different by Turkey test (p<0.05)

A maximum male and female adults longevity of *Sitotroga cereallea* was observed on 30ºC temperature (15.41±0.65 female, 12.44±0.81 male), followed by 35ºC temperature (15.24±0.56 female, 12.34±0.65 male), 25ºC temperature (14.47±1.02 female, 11.04±0.27 male) and 20ºC temperature (12.01±0.78 female, 9.34±0.13 female), while a minimum male and female adults longevity of *Sitotroga cereallea* was observed on 15ºC temperature (11.34±0.13 female, 9.14±0.23 male). Statistically, significant difference was observed on 15ºC and 20ºC temperature when it was compared with 25ºC, 3 ºC and 35ºC temperatures. Whereas statistically no significant difference was noticed among 25ºC, 30ºC and 35ºC temperature regimes as mentioned in Table-9.

Discussion

The rate of development, metabolism, growth, reproduction, general behaviour, and spread of insect pests are all influenced by temperature, which is an essential component of the environment. In this study, five different temperatures (15°C, 20°C, 25°C, 30°C, and 35°C) were utilized to manage the Angoumois grain moth in a laboratory setting. In present results we observed that Results revealed that a maximum incubation period of *Sitotroga cereallea* eggs was observed on 15 ºC temperature (6.34±0.13) and 20 ºCtemperatures (6.01±0.78). While a minimum incubation period of *Sitotroga cereallea* eggs was observed on 30ºC temperature (3.02±0.65). A maximum hatching % of eggs *Sitotroga cereallea* was observed in 25 ºC temperature (91.47±1.02). While a minimum hatching % of eggs *Sitotroga cereallea* was observed in 15º Ctemperature (70.34±0.13) (Table-1 and 2). Similerly results also were observed by Demissie et al., (2014) who reported that below 25ºC temperature have negative impact on the hatching % of eggs and incubation periods of insects. Similar results also were noticed by Mendoza et al (2004) who reported that under cold temperature insects increased their incubation periods. A maximum larval mortality of Angoumois grain moth, *Sitotroga cereallea* was observed on 15 ºC temperature (33.34±0.13). While a minimum larval mortality of *Sitotroga cereallea* was observed on 30ºC temperature (11.02±0.65). A maximum larval development period of *Sitotroga cereallea* was observed on 15ºC temperature (23.34±0.13) and 20ºC temperature (22.01±0.78). While a minimum larval development period of *Sitotroga cereallea* was observed in 30ºC temperatures (16.02±0.65) (Table-2-3). Our findings are consistent with Akter (2013), who found that *S. cerealella* had the longest development time at temperatures as low as 20 ° C and 24 ° C, and the shortest development period (17.42 days) at temperatures as high as 30 ° C. The length of time it takes for a butterfly to mature decreases dramatically as the temperature rises. The survival of larval stage would be poorest at excessively high or low temperature, according to Wang et al. (2009). Warehouse insects were destroyed at exceptionally hot or low temperatures, according to Burk et al. (2000). They also discovered that a moderately high or low temperature had a lower fatal impact, but it slowed population expansion. According to Howe (1971), the developmental time is an excellent indication for determining the impact of environmental variables on insect growth. Kumaw et at., (2007) found that temperature and relative humidity altered the developmental period of *R. dominia* from egg to adult using this method. At a temperature regime of 30ºC, the largest adult emergence (percentage) of Sitotroga grains was recorded (91.0±20.6). At 15 ºC, a minimum adult emergence percentage of *Sitotroga cereallea* (69.3±40.13) was detected. A maximum Pupal period of Sitotroga *cereallea* was observed on 15ºC (7.34±1.02). While minimum pupal period of *Sitotroga cereallea* was observed on 30ºC (4.02±0.65). agreed with the results of El-Nahal et al (1978) who examined that effects of temperature and humidity variation on developmental stages of Grain moth hence the developmental stages and cause mortality in this resting stage. A maximum male and female adult's longevity of *Sitotroga cereallea* was observed on 30ºC temperature (15.41±0.65 female, 12.44±0.81 male) and 35ºC temperature (15.24±0.56 female, 12.34±0.65 male). While a minimum male and female adults longevity of *Sitotroga cereallea* was observed on 15ºC temperature (11.34±0.13 female, 9.14±0.23 male) (Table-9). Females live longer than males, according to the authors, which was also supported in this study. According to Hill (2019), S. cerealella larvae may complete their development in 19 days at a temperature of 25°C and 80% relative humidity. The scientists determined that temperatures between 25 and 30 degrees Celsius and a RH of 80 percent were ideal for the development, survival, and reproduction of stored grain insect pests. The development time reduces with rising temperature at all levels of relative humidity. However, at low temperatures, the time required to complete development has increased significantly. Although high levels (e.g., 70–80 percent RH) are clearly beneficial, relative humidity appears to have a smaller effect. According to Speight et al. (1999), an insect's body temperature is a function of its environment; hence its inability to manage that function affects its developmental period. According to Sousa et al. (2009), the most important determinants for insect abundance are food availability and quality, as well as environmental conditions such as temperature and humidity. They discovered that such parameters impacted insect abundance during development, survival, and reproduction. Ileleji et al., (1992) also found that temperature and relative humidity have a significant impact on warehouse insect survival (2007). Most stored grain insects had an ideal growth period between 25–35° C. A maximum fecundity of Sitotroga. cerealella was observed on 30 oC temperature (272.02±0.65), while a minimum of *Sitotroga cereallea* was observed in 15ºC temperature (185.34±0.13). A maximum oviposition rate of *Sitotroga cereallea* was observed on 30ºC temperature (17.65±0.65) and 25ºC temperature (17.03±1.02). While a minimum oviposition rate of *Sitotroga cereallea* was observed on 35ºC temperature (13.97±0.56) (Table-7 and 8). El-Nahal (1978) found that the duration of the egg stage, as well as the duration of the fecundity and oviposition stages, and the adult life-span for S. cerealella raised at various temperatures, was inversely linked with temperature (the optimum for hatching being at 27 ºC). The largest number of eggs was also deposited at 30o C, according to this author. This idea is in line with what we have learned so far. Although the ideal environmental conditions for the growth and development of S. cerealella are between 25 and 35 degrees Celsius, the insect's ability to complete development at 15 or 35 degrees Celsius and 43 percent relative humidity allows it to attack stored grains not only in tropical and subtropical climates. , but also in cooler climates. Kumaw et al., (2007) obtained similar results, reporting that *R. dominica* reached maximum fertility at 30±1 °C with 75 ± 5% relative humidity. In contrast, Hagstrum and Milliken (1988) found that at temperatures below 22.5 ° C and above 35 ° C, they cannot survive and perish. This discrepancy may be related to the wheat moth strains and media used in this investigation (Edde, 2012). According to this study, any increase in temperature up to 34° C favors the growth of grain moths, while any increase in temperature above 34 ° C has a negative effect. Similarly, an increase in relative humidity levels usually benefits growth; however the response is more diverse. Das and Chauduri (2005) found that temperature and relative humidity have a significant effect on the growth and development of insects. Temperature relative humidity quantity and quality of feed have been shown to be the most critical growth parameters influencing the development of angomouise grain moths by Hagstrum and Milliken (1988). Furthermore, they found that the influence of moisture and food on larval growth was more pronounced than the effect of temperature at near -ideal developmental temperatures. Our findings may be used to establish the best storage settings to prevent Angoumois grain moth damage, as well as to estimate relative damage potential as a function of temperature. It cannot be said that storing grains below 15 ° C is not conducive to the growth of Angoumois seed moths.

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