International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 08-08-2021, Accepted: 23-08-2021, Published: 08-09-2021
Volume 6, Issue 5, 2021, Page No. 16-20

The effect of temperature and relative humidity on the development of the bean weevil, *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae)

Mehmet Karakas
Department of Biology, Science Faculty, Ankara University, Tandogan, Ankara, Turkey

Abstract
Adults of laboratory population of the bean weevil, *Acanthoscelides obtectus* was exposed at the temperature of 23 º, 26 º and 30 ºC and relative humidity of 65%, 70% and 75% RH to determine egg lying, larvae, pupae and adult emergence time and progeny production/reduction in laboratory culture at mentioned environmental conditions. Three replications were used for each application. Twenty four pairs of adults were released to get eggs. Data regarding oviposition, fertility and adult emergence was recorded on daily basis. *Acanthoscelides obtectus* has great influence of temperature and relative humidity on its life period. It exhibited high appearance at high temperature in comparison with low temperature. Relative humidity has also excessive influence on the development of *A. obtectus*.

Keywords: *Acanthoscelides obtectus*, the bean weevil, development, temperature, relative humidity

Introduction

Bean weevils are originally native to Central America, however grain shipments at the end of the 19th century introduced the species to Europe where it subsequently spread around the globe. It is now found in Europe, Asia, North and South America, Africa, Australia and elsewhere (Cabi/Eppo, 2002) [1].

Bean weevils develop and feed upon leguminous plants, such as beans, vetch, alfalfa, soybean, peas and lentils. It may reduce yields by 60%. Due to feeding inside seeds, it may not be noticed until much of the crop is infested. Partially damaged seeds lose their germinating ability and taste quality (Cipollini and Stiles, 1991) [2].

Bean weevil, *Acanthoscelides obtectus* Say, 1831 is a warm-climate species, with optimal temperatures around 27-29 ºC for adults, 24-27 ºC for larvae and 22-26 ºC for pupa. Temperatures higher or lower than this can cause a decrease in a number of eggs lain and they are very vulnerable to temperatures below 0 ºC. Female bean weevils lay eggs onto seed pots or into them by chewing holes, in groups of 2 to 20 eggs. A single female can lay up to 200 eggs, but 40 is average fecundity. Egg development can take 30 to 45 days before a first instar larvae emerges. After approximately 3 days the larvae then moults and becomes a second instar larvae which then begin to consume the seed, with the larval stage lasting 3 to 3,5 weeks in total. The larvae then pupates inside the seed, taking 9 to 29 days. The life cycle of a single generation takes from 100 to 110 days. If the seeds are stored in a warm place multiple generations can be produced one after another (Pfaffenberger, 1985; Saqpunaru *et al*., 2006) [3, 4].

Temperature (ºC) and relative humidity (RH) are two of the most important environmental factors affecting the development of insects. Depending on these two environmental factors, effective applications can be made on physical control of insects. These types of applications are also very safe methods in terms of human, animal and environmental health. Many researchers have done different researches on different insects from past to present (Rachvelishvili, 1975; Shavrina, 1988) [5, 6].

In order to develop economical and effective control measures for stored product pests, detailed and accurate knowledge of its bio-ecology is essential along with possible prediction of population levels and study of the various mortality factors affecting its abundance. The life cycle of these insects varies with temperature, relative humidity and diet. Shazali and Smith (1985) [7], reported that total development time of maize weevil, *Sitophilus zeamais* from egg to adult, was completed in 25 days when reared on sorghum at 30 ºC and 70% RH. Total development time was 28 days when the insects were reared on maize kernels mixed with some flour at 30 ºC and 80% RH (Grewal and Atwal, 1967) [8] and 36 days when the insects were reared in maize at ambient temperature and relative humidity (Koone, 1952) [9]. Larval infestation leaves no visible symptoms on grains. According to Hill (1990) [10], total larval development of *Sitotroga cerealella* can be completed in 19 days at 30 ºC and 80% RH. Temperature limits growth at 16 ºC and 35 ºC, and humidity between 50-90% appears to have little effect on the rate of growth.

Grewal and Atwal (1967) [8] concluded that 25 – 30 ºC and 80% RH are optimal for the development, survival, and reproduction of *S. cerealella* strain. The maximum population growth of *S. cerealella* occurred at 30 ºC. High relative humidity and temperatures higher than 30 ºC are not suitable for this pest to thrive.

In physical management; high and low temperature (hot water, hot steam, solarisation, burning, cooling, etc.), atmospheric gases, proportional humidity, immersion in water, sound, mineral substances and radiation can be used (Shevchenko, 1970) [11].

Stored crop pests can survive and multiply only in a narrow temperature range. At temperatures outside this range, the pest population either remains stable or dies quickly or at low rates. Low temperature application has two important effects on stored product pests; i) growth rate, nutrition and

reduction of fertility, ii) lower survival. Temperatures between 15 and 25 °C cause less spawning, slower growth, less movement, and a longer life span. Different methods can be used to lower the temperature of the grain stack. It can be circulation (mixing, transfer) of products, ventilation of the environment or cooled ventilation. If possible, some products can be stored in cold places or cold storage, which can greatly benefit the product by halting or minimizing pest activity (Fields, 2006) [12]. However, it is stated that the humidity level should be 13% especially for cold weather applications (Salha *et al.*, 2009) [13].

It has been known for thousands of years that stored product pests are affected by high temperatures. The first written document for high temperature application was found in Chinese records 1500 years ago (Fields, 1992) [14]. The application of high temperature is already applied on a large scale in warehouses and equipment. This application can be applied to grain as well as warehouses (Fields, 2006) [12]. The effects of high temperature on insects can be summarized as follows; It causes water loss (Dehydration) in insects, melting of cell membranes, damage to enzymes and changes in Salt balance (Fields, 2006) [12]. Temperatures higher than the highest growing temperature for insects can cause the insects to die quickly. At temperatures above 45 °C, most storage pests die within 24 hours. It is very difficult to compare the results of these studies because the methods of heating the grains, the insects they are applied to, the application times and temperatures are very different (Fields, 2006) [12]. Depending on the type of product and the type of the pest, this period is 47 hours for 4 hours of application, 3 hours for 54.4 °C and a few minutes for 55.5 ° C. Most of the insects and eggs die in these practices (Hammond, 2015) [15]. Temperatures above 50 °C are completely fatal for *Rhyzopertha dominica*. Application times of 2 and 0.5 hours are required for *Tribolium castaneum* and *Tribolium confusum*, and 49-51 °C for *Cryptolestes turcicus* (Adler, 2010) [16]. There are two important issues to be considered in temperature applications; prevention of energy loss and good temperature distribution (Hammond, 2015) [15]. The response of common stored crop pests to temperatures is different (Bank and Fields, 1995; Fields, 2006; Das *et al*., 2013) [17, 12, 18].

The main water source of stored product pests is food. The moisture content of foods affects the number of offspring, growth rate, life expectancy and adulthood. Stored product pests cannot survive and multiply at relative humidity below 50%. This method can be applied especially in warehouses (Yıldırım *et al*., 2001; Fields, 2006) [19, 12].

In this study, the effects of different temperature and humidity combinations on different developmental stages of the bean weevil, *A. obtectus* were investigated. This research is aimed to provide support to physical control, which is one of the methods of controlling stored seed pests.

Materials and Methods

Rearing of *Acanthoscelides obtectus*

In this study, *A. obtectus* laboratory stock, which is being maintained since 2019, on the dry bean seeds under laboratory conditions (28 ± 2 °C and 65 ± 5% RH). Newly emerged adult *A. obtectus* were transferred from stock culture to the new culture containers and oviposition was provided for 48 hours. After this time, adult individuals were removed from the culture and new adult emergence were provided and these individuals were selected for the experiment.

Application procedures for temperature and relative humidity

Twenty four pairs of insects obtained from laboratory culture were released to 100 grams of sterilized dry bean seeds in a glass jar (500 ml) and then placed inside an incubator was maintained at one of three different temperature (23, 26 and 30 ºC) levels. The relative humidity applications (65, 70 and 75% RH) within the incubators were maintained by using saturated salt solutions. All incubators were held at a photoperiod of 12h: D – 12h: L hours for the ideal life cycle of the bean weevil, *A. obtectus*. Oviposition was allowed for 48h. This time period of egg laying of mature females of wheat weevils ensures that sufficient amount of eggs are laid. After 48h, released insects were removed and their total number of eggs laid on randomly selected sixty grains of bean were counted with help of a binocular. These eggs were maintained for life stages of the bean weevil, *A. obtectus*.

Developmental practice

For fertility test, thirty females were released in different glass jars (425 ml) to observe the fertility rate in different (5, 10, 15, 20 and 25) days.

For larval emergence test, thirty eggs were released in petri dishes (90 mm diam.) at each temperature and relative humidity combination. The data was taken about egg hatching after 4, 8, 15, 21 and 28 days.

For pupae emergence test, the hatched eggs were released in different petri dishes to observe the larval time periods. Larvae took prolong time period to complete its four instars so data about pupae formation were taken after 7, 14, 20, 25, 29 and 32 days.

For adult emergence test, the thirty pupae were transferred into new petri dish with great care. The data regarding adult emergence was observed after 5, 10, 15, 20 and 25 days.

Statistical data

Data on the developmental stages of the insect was analysed by a two way analysis of variance (ANOVA) and the Tukey test was used as a post-hoc analysis (the multiple comparison techniques to determine the difference between groups in researches) for the interaction and effect of temperature and relative humidity. Mean values of the entire developmental time within one replicate of each treatment were calculated.

Results

The results showed that temperature and relative humidity greatly affect the life cycle of *A. obtectus* (F= 4.88; P= 0.071). The egg lying of bean weevil was found maximum (24.00 ± 0.57) at 30 ºC and 75% RH after 12 days but when the decrease in temperature from 30 ºC to 26 ºC and 23 ºC, relative humidity from 75% to 70% and 65%, the egg lying by wheat weevils also reduced to 13.33 ± 0.58, 10.66 ± 0.88 and 10.33 ± 0.33 respectively as mentioned in Table 1. The combined effect of temperature and relative humidity influenced the larval emergence from eggs of *A. obtectus* (F= 4.60; P= 0.093) as Table 2 showed that larval emergence was also increased from 11.33 to 27.33 as both factors increased from lowest point (23 ºC and 65% RH) to highest point (30 ºC and 75% RH) after 28 days of

observation. The results regarding pupae emergence was also greatly significant different due to temperature and relative humidity variation (F= 4.65; P= 0.096). The pupae emergence increased from 11.33 ± 0.33 and 28.33 ± 0.33 as both combined treatments (30 ºC and 75% RH) but decreased to 16.33 ± 0.39 and 15.00 ± 0.45 as both factors fall down to 26 and 23 ºC, 70 and 65% RH respectively after 29 days of observation as shown in Table 3. The increase in adult emergence from pupae of bean weevil was observed in Table 4 from 11.33 ± 0.33 to 28.67 ± 0.67 due to the effect of temperature and relative humidity (F= 4.88; P= 0.05). So F and P values showed that both temperature and relative humidity affect the whole life period of bean weevil.

Table 1: Mean values of egg lying period ± standard error (ELP ± SE) of *Acanthoscelides obtectuss* after different days under different temperatures (ºC) and relative humidity (RH).

ºC / % RH	ELP ± SE / Days				
	5	10	15	20	25
23 / 65	5.33 ± 0.33 ^{c}	5.33 ± 0.88 ^{c}	7.33 ± 0.88 ^{c}	7.33 ± 0.88 ^{c}	10.33 ± 0.33 ^{c}
23 / 70	8.33 ± 0.33 ^{b}	9.33 ± 0.33 ^{b}	9.66 ± 0.33 ^{b}	9.66 ± 0.88 ^{b}	11.00 ± 0.33 ^{b}
23 / 75	11.33 ± 0.57 ^{f}	12.33 ± 0.66 ^{f}	12.66 ± 0.66 ^{f}	13.00 ± 1.20 ^{f}	14.00 ± 0.58 ^{f}
26 / 65	6.00 ± 0.33 ^{ef}	6.33 ± 0.33 ^{ef}	6.33 ± 0.33 ^{ef}	8.66 ± 0.88 ^{ef}	10.66 ± 0.88 ^{ef}
26 / 70	10.33 ± 0.33 ^{ef}	11.00 ± 0.57 ^{ef}	12.33 ± 0.57 ^{ef}	13.00 ± 0.58 ^{ef}	15.33 ± 0.67 ^{ef}
26 / 75	15.33 ± 0.67 ^{e}	16.00 ± 0.57 ^{e}	16.66 ± 0.33 ^{e}	18.33 ± 1.00 ^{e}	19.33 ± 0.33 ^{e}
30 / 65	9.33 ± 0.33 ^{d}	10.33 ± 0.33 ^{d}	10.33 ± 0.33 ^{d}	11.33 ± 0.66 ^{d}	13.33 ± 0.58 ^{d}
30 / 70	14.33 ± 0.58 ^{d}	14.33 ± 1.45 ^{d}	14.33 ± 1.45 ^{d}	16.00 ± 0.57 ^{d}	18.33 ± 0.66 ^{d}
30 / 75	19.33 ± 0.33 ^{a}	20.33 ± 0.67 ^{a}	20.33 ± 0.67 ^{a}	22.00 ± 0.57 ^{a}	24.00 ± 0.57 ^{a}
Statistical analysis	F= 4.17 ** P= 0.083	F= 4.10 ** P= 0.076	F= 1.00 * P= 0.50	F= 3.99 ** P= 0.057	F= 4.88 ** P= 0.071

Each column, mean value followed by same latter are not significant to each other.
The Tukey HSD test ≤ 0.05. (*non-significant, **significant, ***extremely significant)

Table 2: Mean values of larvae emergence period ± standard error (LEP ± SE) of *Acanthoscelides obtectus* after different days under different temperatures (ºC) and relative humidity (RH).

ºC / % RH	LEP ± SE / Days				
	4	8	15	21	28
23 / 65	5.87 ± 040 ^{d}	6.33 ± 0.88 ^{d}	7.33 ± 0.33 ^{d}	9.67 ± 0.40 ^{d}	11.33 ± 0.33 ^{d}
23 / 70	8.33 ± 0.33 ^{cd}	8.33 ± 0.67 ^{cd}	8.66 ± 0.88 ^{cd}	12.66 ± 0.66 ^{cd}	14.67 ±0.58 ^{cd}
23 / 75	12.33 ± 1.11 ^{cf}	13.66 ± 0.67 ^{cf}	11.67 ± 0.40 ^{cf}	15.67 ± 0.45 ^{cf}	17.00 ± 0.57 ^{cf}
26 / 65	6.66 ± 0.40 ^{ef}	7.67 ± 0.33 ^{ef}	14.66 ± 0.45 ^{ef}	10.67 ± 0.40 ^{ef}	13.33 ± 0.33 ^{ef}
26 / 70	11.66 ± 0.88 ^{ef}	12.33 ± 1.11 ^{ef}	9.33 ± 0.33 ^{ef}	13.33 ± 0.37 ^{ef}	16.67 ± 0.45 ^{ef}
26 / 75	14.66 ± 1.00 ^{e}	15.33 ± 0.39 ^{e}	13.33 ± 0.33 ^{e}	20.00 ± 0.57 ^{e}	23.66 ± 0.88 ^{e}
30 / 65	11.66 ± 0.33 ^{b}	13.33 ± 1.11 ^{b}	17.00 ± 0.57 ^{b}	15.33 ± 0.39 ^{b}	16.33 ± 0.39 ^{b}
30 / 70	15.00 ± 0.58 ^{b}	16.33 ± 0.58 ^{b}	17.00 ± 0.45 ^{b}	19.00 ± 1.00 ^{b}	21.33 ± 0.33 ^{b}
30 / 75	19.66 ± 0.33 ^{a}	21.33 ± 0.33 ^{a}	22.66 ± 0.88 ^{a}	24.00 ± 0.57 ^{a}	27.33 ± 0.33 ^{a}
Statistical analysis	F= 4.87 ** P= 0.063	F= 4.98 ** P= 0.073	F=4.68 ** P= 0.073	F= 4.60 ** P= 0.090	F= 4.60 ** P= 0.093

Each column, mean value followed by same latter are not significant to each other.
The Tukey HSD test ≤ 0.05. (* non-significant, ** significant, *** extremely significant)

Table 3: Mean values of pupae emergence period ± standard error (PEP ± SE) of *Acanthoscelides obtectus* after different days under different temperatures (ºC) and relative humidity (RH).

ºC / %RH	PEP ± SE / Days					
	7	14	20	25	29	32
23 / 65	2.87 ± 0.33 ^{c}	8.33 ± 0.33 ^{c}	8.66 ± 0.40 ^{c}	9.33 ± 0.38 ^{c}	11.33 ± 0.33 ^{c}	8.66 ± 0.40 ^{c}
23 / 70	8.33 ± 0.33 ^{b}	12.67 ± 0.33 ^{b}	14.33 ± 0.33 ^{b}	12.67 ± 0.33 ^{b}	15.00 ± 0.45 ^{b}	12.67 ± 0.33 ^{b}
23 / 75	11.67 ± 0.40 ^{f}	14.00 ± 0.57 ^{f}	18.67 ± 0.33 ^{f}	14.00 ± 0.57 ^{f}	20.67 ± 0.33 ^{f}	15.33 ± 0.33 ^{f}
26 / 65	5.66 ± 0.33 ^{ef}	9.33 ± 0.33 ^{ef}	10.33 ± 0.33 ^{ef}	9.33 ± 0.33 ^{ef}	13.00 ± 0.57 ^{ef}	9.33 ± 0.33 ^{ef}
26 / 70	10.33 ± 0.33 ^{ef}	12.00 ± 0.57 ^{ef}	15.33 ± 0.33 ^{ef}	13.00 ± 0.57 ^{ef}	17.33 ± 0.33 ^{ef}	13.00 ± 0.57 ^{ef}
26 / 75	16.33 ± 0.33 ^{e}	18.33 ± 0.33 ^{e}	23.66 ± 0.88 ^{e}	18.33 ± 0.33 ^{e}	24.66 ± 0.88 ^{e}	18.33 ± 0.33 ^{e}
30 / 65	8.33 ± 0.33 ^{d}	16.33 ± 0.33 ^{d}	12.67 ± 0.33 ^{d}	16.33 ± 0.33 ^{d}	16.33 ± 0.39 ^{d}	16.33 ± 0.33 ^{d}
30 / 70	14.33 ± 0.33 ^{d}	15.33 ± 0.33 ^{d}	21.00 ± 0.57 ^{d}	15.33 ± 0.33 ^{d}	23.66 ± 0.88 ^{d}	15.33 ± 0.33 ^{d}
30 / 75	20.67 ± 0.33 ^{a}	21.33 ± 0.67 ^{a}	26.67 ± 0.33 ^{a}	21.33 ± 0.67 ^{a}	28.33 ± 0.33 ^{a}	21.66 ± 0.33 ^{a}
Statistical analysis	F= 4.98 ** P= 0.093	F= 4.65 ** P= 0.093	F= 4.44 ** P= 0.093	F= 4.65 ** P= 0.096	F= 4.65 ** P= 0.096	F= 4.07 * P= 0.100

Each column, mean value followed by same latter are not significant to each other.
The Tukey HSD test ≤ 0.05. (* non-significant, **significant, ***extremely significant)

Table 4: Mean values of adult emergence period ± standard error (AEP ± SE) of *Acanthoscelides obtectus* after different days under different temperatures (ºC) and relative humidity (RH).

ºC / % RH	AEP ± SE / Days				
	5	10	15	20	25
23 / 65	3.33 ± 0.33 ^{b}	5.67 ± 0.33 ^{b}	9.66 ± 0.88 ^{d}	9.67 ± 0.67 ^{d}	11.33 ± 0.33 ^{d}
23 / 70	7.33 ± 0.33 ^{f}	11.67 ± 0.33 ^{f}	16.33 ± 0.67 ^{f}	18.67 ± 0.33 ^{f}	19.33 ± 0.33 ^{f}

23 / 75	12.33 ± 0.33 [f]	16.67 ± 0.33 [f]	20.33 ± 0.33 [f]	22.00 ± 0.57 [f]	25.33 ± 0.57 [f]
26 / 65	6.67 ± 0.33 [e]	10.33 ± 0.33 [e]	12.67 ± 0.33 [e]	14.00 ± 0.57 [e]	14.33 ± 0.33 [e]
26 / 70	11.33 ± 0.33 [de]	15.00 ± 0.57 [de]	17.33 ± 0.67 [de]	21.67 ± 0.33 [de]	22.00 ± 0.57 [de]
26 / 75	14.33 ± 0.33 [d]	18.33 ± 0.33 [d]	21.67 ± 0.33 [d]	24.00 ± 0.57 [d]	25.66 ± 0.67 [d]
30 / 65	10.67 ± 0.33 [c]	14.67 ± 0.33 [c]	17.33 ± 0.67 [c]	18.33 ± 0.33 [c]	19.33 ± 0.33 [c]
30 / 70	16.47 ± 0.33 [c]	20.33 ± 0.33 [c]	21.67 ± 0.33 [c]	23.00 ± 0.57 [c]	25.33 ± 0.33 [c]
30 / 75	22.33 ± 0.33 [a]	26.33 ± 0.33 [a]	26.66 ± 0.67 [a]	27.00 ± 0.57 [a]	28.67 ± 0.67 [a]
Statistical analysis	F= 6.12 [***] P= 0.01	F= 6.49 [***] P= 0.01	F= 6.89 [***] P= 0.01	F= 5.01 [***] P= 0.01	F= 4.88 [**] P= 0.05

Each column, mean value followed by same latter are not significant to each other.
The Tukey HSD test ≤ 0.05. ([*] non-significant, [**] significant, [***] extremely significant)

Discussion

The most favourable conditions for the beetles are the temperatures 27-29 ºC, 24-27 ºC for larvae and 22-26 ºC for pupa. Higher and lower temperatures cause a decrease of fecundity. The species is very sensitive to temperatures below zero. The bean weevil prefers high humidity, 80-88%. It gives 2-5 (2 in fields) generations in conditions of Transcaucasia and Middle Asia; 3-4 (1 in field) in Krasnodar Territory, Ukraine, Moldova, Byelorussia, Kazakhstan. The largest number and harming activity are observed at the end of June and in July (Egorov, 1989) [20].

Under higher temperature conditions, the development of eggs, larvae and pupae is shortened, a characteristic phenomenon for large group forest species (Szujecki, 1998) [21]. The faster development of the preimaginal stages means shorter exposure to adverse environmental conditions such as low temperature, too high or insufficient humidity, predator and parasitoid attacks, and the activity of the entomopathogen. It can result in reproductive success of many insect species. Temperature influence on a length of larval development has been observed under laboratorial conditions for two significant species of native foliophages: the nun moth, *Lymantria monacha* L. and the gypsy moth *Lymantria dispar* L. (Karolewski *et al*., 2007) [22]. In both cases, the increase in temperature was effective in shortening the growth time from the egg stage to the pupae. Different results have been obtained regarding larva survivability of both species. When the average environment temperature has increased, higher mortality has been observed for caterpillars of *L. monacha*. Whereas the survivability of *L. dispar* larvae has increased. These differences probably result from two different thermal optima for both species reflected in varied environmental preferences. The results of the described experiment present variety of climate parameters' influence on the insect development, even when closely related species are compared.

Unlike temperature, humidity is characterized by higher variability. It is difficult to point out a clear trend in humidity as well as in temperature. The basic climate parameters, i.e. temperature and humidity, influence insects both directly and indirectly. The faster development of the preimaginal stages means shorter exposure to adverse environmental conditions such as low temperature, too high or insufficient humidity, predator and parasitoid attacks, and the activity of the entomopathogen. It can result in the reproductive success of many insect species. Temperature and humidity change can influence insects indirectly by changes in host plants metabolism and physiology (Ayres and Lombardero, 2000; Rouault *et al.*, 2006; Moore and Allard, 2008; Netherer and Schopf, 2010) [23, 24, 25, 26]. Changing thermal conditions and humidity both can have positive and negative influence on insects. Battisti (2008) [27] has given an example of two forest phytophages on which temperature increase had significantly different influence. On the one hand, higher temperature and low humidity caused shorter development of larvae of *Cephalcia arvensis*; on the other hand, enabled faster pupation and avoiding the longer diapause. Climate changes are important for phytophagous insect species, and basic climate parameters – temperature and humidity – influence it both directly and indirectly.

Conclusion

From this study, it was concluded that at 26 and 30 °C, the growth time of bean weevil is very short, therefore it shows more population growth below 26 °C or above 30 °C which was not unsuitable for growth. Temperature and relative humidity can greatly affect the life stage of stored grain pests such as bean, wheat, maize and rice weevil species. It can be used in combination with any chemical or physical measure because these factors can increase the pest's effectiveness against them and reduce their resistance.

References

1. CABI/EPPO. *Acanthoscelides obtectus*. Distribution Maps of Plant Pests, Wallingford, UK: CAB International, 2002, 625.
2. Cipollini ML, Stiles EW. Seed predation by the bean weevil *Acanthoscelides obtectus* on *Phaseolus* species: consequences for seed size, early growth and reproduction. Oikos,1991:60(2):205-214.
3. Pfaffenberger GS. Description, differentiation, and biology of the four larval instars of *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). Coleopterists Bulletin,1985:39(3):239-256.
4. Saqpunaru T, Filipescu C, Georgescu T, Bild YC. Bioecology and control of bean weevil (*Acanthoscelides obtectus* Say.). Cercetari Agronomice în Moldova,2006:39(2):5-12.
5. Rachvelishvili EV. Biological features of bean weevil (*Acanthoscelides obtectus* Say) in Georgia. In: Kanchaveli L.A., ed. Proceedings of Georgian plant protection institute, Tbilisi: Georgian NIIZR. (in Russian),1975: 27:44-47.
6. Shavrina EA. About temperature and humidity influence on bean weevil number and damaging haricot-bean seeds at keeping conditions. In: Novozhilov K.V., ed. Proceedings of VIZR, N. Leningrad: VIZR, (in Russian),1988:71:34-56.
7. Shazali MEH, Smith RH. Life history studies of internally feeding pests of stored sorghum: *Sitotroga cerealella* (Ol.) and *Sitophilus oryzae* (L.). Journal of Stored Product Research,1985:21:171-178.
8. Grewal SS, Atwal AS. The influence of temperature and humidity on the development of *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae). Journal of Agricultural Research,1967:6:353-358.

9. Koone HD. Maturity of corn and life history of the Angoumois grain moth. Journal of Kansas Entomological Society,1952:25:103-105.
10. Hill DS. Pests of stored products and their control. S. K. Jain for CBS Publishers & Distributors (Pvt.) Ltd. New Delhi, 1990, 152-153.
11. Shevchenko MI. Ecological features of bean weevil and basis for control measures. In: Zakolodina-Mitina L.A., ed. Plant protection against agricultural pests, diseases, weeds in Pskov region (Proc. of Velikie Luki agricultural institute). Velikie Luki: SKhI,197011:24-28.
12. Fields PG. Alternatives to chemical control of stored product insects in temperate regions. 9th International Working Conference on Stored Product Protection, São Paulo, Brazil, 2006, 653-662.
13. Salha H, Kalinovic I, Ivezic M, Rozman V, Liska A. Application of low temperatures for pests control in stored maize. 7th Croatian congress of cereal technologists Flour-Bread, Opatija, Hrvatska, 2009, 608-616.
14. Fields PG. The control of stored-product insects and mites with extreme temperatures. Journal of Stored Products Research,1992:28:89-118.
15. Hammond D. Heat treatment for insect control: developments and applications, Woodhead Publishing Series in Food Science, Technology and Nutrition, Number, Cambridge, UK,2015:241:95.
16. Adler C. Physical control of stored product insects. JuliusKühn-Archiv,2010:429:33-35.
17. Bank J, Fields PG. Physical methods for insect control in stored-grain ecosystems, Marcel Dekker, New York, 1995, 353-409.
18. Das I, Kumar G, Shah NG. Microwave heating as an alternative quarantine method for disinfestation of stored food grains. International Journal of Food Science, 2013, 1-13.
19. Yildirim E, Ozbek H, Alan I. Depolanmış ürün zararlıları, Atatürk Üniversitesi Ziraat Fakültesi Yayınları, Erzurum,2001:191:117.
20. Egorov AB. Review of weevil-beetles (Coleoptera, Bruchidae) of the genus *Acanthoscelides* Schilsky in "Fauna of the USSR" (Lukyanovich & Ter-Minasyan, 1957). Entomologicheskoe obozrenie, (in Russian),1989:68:748-758.
21. Szujecki A. Entomologia leśna. Warszawa, Wyd, SGGW, 1998.
22. Karolewski P, Grzebyta J, Oleksyn J, Giertych MJ. Effects of temperature on larval survival rate and duration of development of *Lymantria monacha* (L.) on needles of *Pinus silvestris* (L.) and of *L. dispar* (L.) on leaves of *Quercus robur* (L.). Polish Journal of Ecology,2007:55(3):595-600.
23. Ayres MP, Lombardero MJ. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. The science of the total environment,2000:262(3):263-286.
24. Rouault G, Candau JN, Lieutier F, Nageleisen LM, Martin JC, Warzée N. Effects of drought and heat on forest insect populations in relation to the 2003 drought in Western Europe. Annals of Forest Science,2006:63(6):613-624.
25. Moore BA, Allard GB. Climate change impacts on forest health. Forest Health & Biosecurity Working Papers FBS/34E. Forest Resources Development Service, Forest Management Division, FAO, Rome, 2008.
26. Netherer S, Schopf A. Potential effects of climate change on insect herbivores in European forests-General aspects and the pine processionary moth as specific example. Forest Ecology and Management,2010:259:831-838.
27. Battisti A. Forests and climate change – lessons from insects. I Forest,2008:1:1–5. http://www.sisef.it/iforest/pdf/ Battisti_210.pdf.