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Effects of temperature and relative humidity on the development of *Trogoderma granarium* (coleoptera: dermestidae) under laboratory conditions

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Abstract
Different insect pests cause damage to stored cereals and food products. *Trogoderma granarium* is most destructive pest of stored grains and food products. The variations in temperature and relative humidity affect the growth and development of the storage insect pests. Present investigation was designed to investigate the effects of different combinations of temperatures (25, 30 and 35℃) and relative humidity (60, 70 and 80%) on all the developmental stages (eggs, larvae, pupae and adults) of the *T. granarium* under controlled laboratory conditions. This experiment was conducted by using Completely Randomized Design (CRD). For each treatment combination, three replications were done. To obtain the eggs, counted numbers of adults of mixed sex were released in plastic jars. Then data regarding F_1 adult emergence, percentage of larval development, pupation, fertility and fecundity was calculated. Finally, all the obtained data was subjected to suitable statistical software for analysis of variance at 5% level of significance.

Keywords: *Trogoderma granarium,* temperature, relative humidity, stored grains and development

1. Introduction
Trogoderma granarium is the intrinsic beetle of subcontinent and is the most serious pest of stored products throughout the world including Pakistan due to its high invasion potential (Ramzan and Chahal, 1986 [11]; Campbell and Arbogast, 2004 [3]; Neethirajana *et al*., 2007 [10]; Ahmedani *et al.,* 2009) [1]. It has been considered as one of the 100 most damaging pests in the world (Lowe *et al*., 2000) [7]. The developmental rate and survival of *T.granarium* significantly depends on light, moisture, temperature, season and host species so, by controlling these physical parameters long term control of pest can also be achieved (Ramzan and Chahal, 1986) [11]. The pre-ovipositional and ovipositional period, incubation period, longevity of adults, larval and pupal period of *Trogoderma granarium* show an inverse relationship with temperature as decrease with the increase in temperature maintained under laboratory conditions. These parameters of growth and development also show inverse relationship with humidity as increase with the decrease in humidity (Mansoor *et al*., 2013) [8]. *Trogoderma granarium* fails to develop at 20°C.The optimum temperature at which development of *T. granarium* takes place is 35°C (Riaz *et al.,* 2014) [12]. Room temperature is ideal for reproduction of *T. granarium* but at 41°C it does not develop (Akhlaq *et al*., 2014) [1].
Larval development in *T. granarium* takes place at very low humidity even at 2% RH but it does not take place at temperatures below 21°C. Egg laying of *Trogoderma granarium* starts approximately at 40°C. At cooler temperatures, in 1 to 3 days, egg laying may commence but at 20°C, no eggs are produced and after emergence mating occurs about five days. Egg hatching takes place in 1-2 weeks. An average number of 50-90 eggs are laid by female and roughly dispersed in the host material. Temperature affects the all life stages of *T. granarium*. The whole developmental period is completed in 26-220 days. Optimum temperature for growth of *T. granarium* is 35°C. Below room temperature for a period of time or if larvae are very congested, then diapause will take place. The survival of larvae takes place at a very low temperature even below -8°C. The larvae are sluggish during diapause and pass through molting. In this state, larvae remain for a long period of time (Anonymous 1981) [2].
The development of *Trogoderma granarium* takes place at a very low relative humidity as 2%. The major controlling factor which affects the presence of introduced *T.granarium* may be high relative humidity (Howe and Lindgren 1957) [6]. The current study deals with the role of temperature on survival, egg hatching duration and length of larval, pupal periods and fecundity of *T.granarium.* It may provide some substitute methods of control of *T. granarium* infestation by controlling the temperature of storage facilities. Furthermore, we also focus relative humidity whether growth and development of *T.granarium* are affected by relative humidity and temperature or not.

2. Materials and Methods
Experiments were performed in the Stored Grain Research, Training and Storage Management Cell of Department of Entomology, University of Agriculture, Faisalabad, during the year 2015-16.

1. Insect Collection: Mass Collection of Khapra Beetle, *Trogoderma granarium* was made from the grain market Faisalabad.

2. Insect Rearing: Collected insects was kept in the sterilized plastic jars under optimum conditions in an incubator having uniform temperature and relative humidity of 25-35°C and 60-80% respectively. Wheat grains were utilized as culture media for *Trogoderma granarium*. Adults were sieved out and hundred adults were released in each of the plastic jars having 300g of sterilized wheat grains and covered with muslin cloth. Adults were allowed to mate and lay eggs. Cultures were started from eggs obtained by sieving from oviposition jars containing adults in wheat grains. Preparation of stages before exposure to treatments took place. Eggs were separated from oviposition jars sieving daily; eggs aged 24-48h were exposed to the treatments. Larvae were removed from culture jars and exposed 12d after oviposition. Pupae were obtained by daily separation from culture jars and keep in wheat grains for 24 h before exposure. Newly emerged adults were kept in pre-exposure jars containing wheat grains and will be exposed 7-14 d after emergence.

3. Influence of temperature and relative humidity on oviposition, development, emergence and adult longevity: From the laboratory colony, five pairs of male and female *Trogoderma granarium* were collected and released onto 300 g of wheat grains which were dried to a consistent moisture level and then place inside incubator maintained at one of three different relative humidity (RH) levels. The RH levels in incubator were maintained by using saturated salt solutions (Winston and Bates, 1960) [13]. NaCl was used as Salt for 60, 70 and 80% RH respectively. The temperature 20, 25 or 30°C were maintained in incubator. Oviposition was allowed for 24, 48 and 72 h. This time period for egg laying was ensured that sufficient amount of eggs was laid. After 24, 48 and 72 h released, *Trogoderma granarium* was removed and number of eggs laid on the wheat grains was counted. Developmental times from egg to adult were recorded and rate of adult emergence was calculated based on the number of total eggs and total number of adults emerged. The procedure was replicated 3 times for each temperature and RH condition. The emerged adults from each treatment combination was collected and kept in a Petri dish and they were observed for longevity providing respective temperature and RH combination used during their development.

The observations on incubation period, larval and pupal periods were recorded. The dates of adult emergence were taken to work out the pupal period. For total developmental period, the average period for complete development was calculated taking the weighted means of the time required for egg, larval and pupal periods. The percentage of adult emergence was calculated by counting the adults in each treatment. The growth index was calculated by dividing percentage of adult emergence by total developmental period in days.

3. Results

The experienced temperature and relative humidity demonstrated significant outcomes to the development of *T. granarium*. It revealed improved response to peak temperature 35C° along with 65% R.H at all life stages of Khapra beetle, mean egg laying (11days), mean larval appearance (10 days), mean pupal appearance (45 days) and mean adult appearance (13 days). The mean egg laying was found higher (27.66%) after 11 days which was significantly higher from (20.00%) at 60% R.H and (16.00%) at 55% R.H correspondingly at same temperature. However, *T. granarium* presented lower means of egg laying (11 days) at temperature 25C° along with these three different levels of relative humidity at 65% (18.333%), at 60% (15.333%) and at 55% (9.66%) respectively.

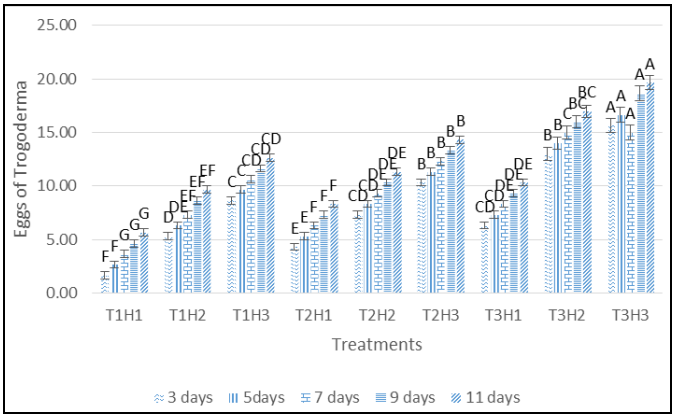

Fig 1: Mean values of egg laying (± S.E) of *Trogoderma granarium* after different days under different temperature (T=25, 30 and 35°C) and different relative humidities (H= 55, 60 and 65%). Each column, mean value followed by same latter are not significant to each other; Tukey and HSD test ≤ 0.05

*= Significant, ** = Highly Significant, NS = Non Significant

The mean larval emergence was found higher (24.66%) after 10 days which was significantly higher from (22.00%) at 60% R.H and (20.33%) at 55% R.H correspondingly at same temperature. However, *T. granarium* presented lower means of larval emergence (10 days) at temperature 25C° along with these three different levels of relative humidity at 65% (19.333%), at 60% (17.00%) and at 55% (14.66) respectively.

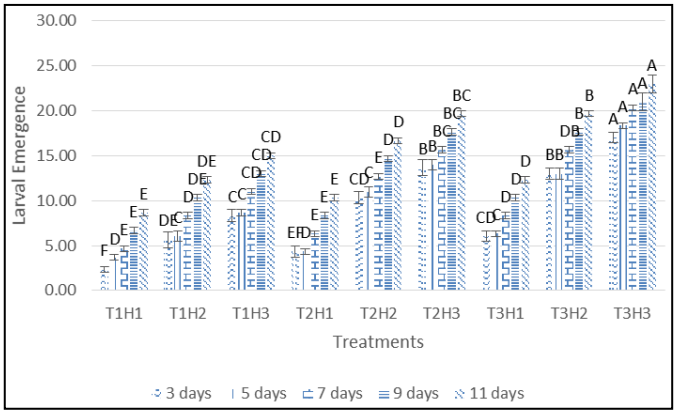

Fig 2: Mean values of larvae emergence (± S.E) of *Trogoderma granarium* after different days under different temperature (T=25, 30 and 35°C) and different relative humidities (H= 55, 60 and 65%). Each column, mean value followed by same latter are not significant to each other; Tukey and HSD test ≤ 0.05

* = Significant, ** = Highly Significant, NS = Non Significant

The mean pupal appearance was found higher (27.66%) after 45 days which was significantly higher from (23.00%) at 60% R.H and (19.00%) at 55% R.H correspondingly at same temperature. However, *T. granarium* presented lower means of larval emergence (45 days) at temperature 25C° along with these three different levels of relative humidity at 65% (19.666 %), at 60% (18.66%) and at 55% (18.33) respectively.

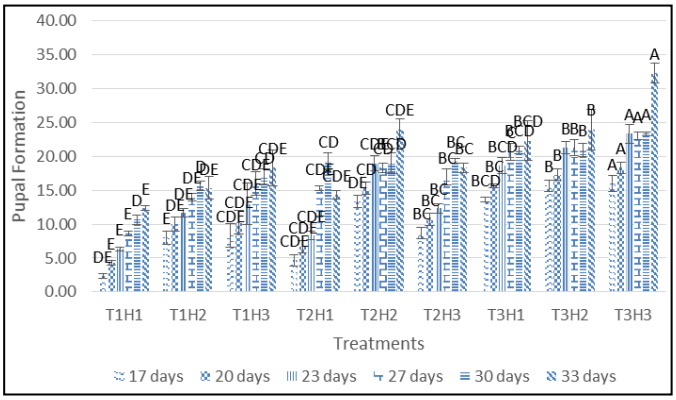

Fig 3: Mean values of pupae formation (± S.E) of *Trogoderma granarium* after different days under different temperature (T=25, 30 and 35°C) and different relative humidities (H= 55, 60 and 65%). Each column, mean value followed by same latter are not significant to each other; Tukey and HSD test ≤ 0.05
* = Significant, ** = Highly Significant, NS = Non Significant

The mean adult appearance was found higher (26.33%) after 13 days which was significantly higher from (22%) at 60% R.H and (18.33%) at 55% R.H correspondingly at same temperature. However, *T. granarium* presented lower means of adult appearance (13 days) at temperature 25C° along with these three different levels of relative humidity at 65% (19.33%), at 60% (16.66%) and at 55% (15.66) respectively.

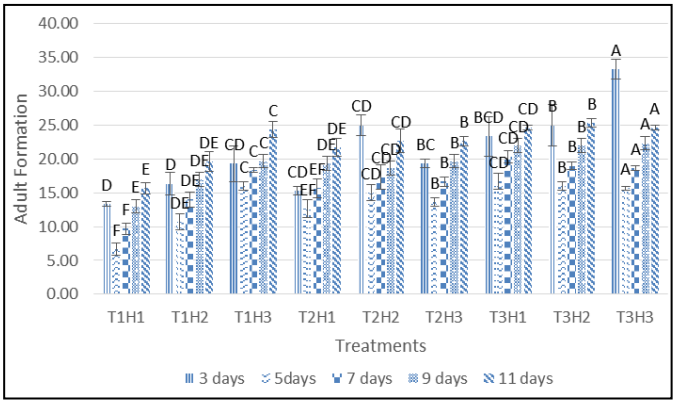

Fig 4: Mean values of adult formation (± S.E) of *Trogoderma granarium* after different days under different temperature (T=25, 30 and 35°C) and different relative humidities (H= 55, 60 and 65%). Each column, mean value followed by same latter are not significant to each other; Tukey and HSD test ≤ 0.05
* = Significant, ** = Highly Significant, NS = Non Significant.

4. Discussion

The current study revealed the effect of different levels of temperature and relative humidity on egg laying, larval appearance, pupal formation and adult emergence. The pest illusions dry and hot environmental conditions.

Relative humidity has excessive influence on the reproduction of *T. granarium.* At 65% R.H the maximum mean value of adult appearance was significantly higher as compared to adult appearance at 60%. At 60 % R.H adult emergence of khapra beetle was high as compared to that of 55%. It is stated that different relative humidity level such as 60 and 65% is most favorable for its development and 55% level is less favorable for its growth as compared to other levels. These results are relatively comparable to Bhargava *et al.* (2009). From this research study it is decided that temperature 35 C° along with 65% R.H is best grouping to evaluate the developmental stages of *T.granarium* because at this grouping, it showed maximum growth rate as compare to tan that of 25 and 30 C°.

5. Conclusion

The following studies concludes that at 30 and 35°C, the development time period of kapra beetle was very short so it show greater population growth so below 30°C or above 35°C which was not suitable for development hence temperature and relative humidity can greatly affect the life stage of internal pests like *Trogoderma granarium* and can be used as combination with any chemical or physical measures because these factors can increase the efficacy and reduce the resistance of the pest against them.

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