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To study the effect of different temperature and relative humidity on the biology of *Rhizopertha dominica*

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Abstract
A laboratory experiment was conducted at Department of Entomology, Rajasthan college of Agriculture, Udaipur during December, 2013 to December 2015 to study the effect of five temperature (20, 25, 30, 35 and 40°C) and five relative humidity (50, 55, 60, 65 and 70%) on the biology of *Rhizopertha dominica* on wheat grains (variety Lok-1). The combination of 30°C temperature and 70 per cent relative humidity was preferred by the pest where maximum fecundity (240.60 eggs/female), highest egg hatching per cent (87.50) and maximum adult survival per cent (78.83). Minimum incubation period (5.33 days), minimum duration of larval and pupal period (31.17 days) and shortest developmental period from egg to adult stage (36.50 days) was recorded at 35°C temperature and 70 per cent relative humidity, but adult longevity of male and female adult was recorded to 40.80 and 42.00 days, respectively at 35°C temperature and 60 per cent relative humidity. The interaction of temperature and relative humidity at 20°C and 50 per cent retarded the growth and development of *R. dominica* by giving longest hatching period (16.50 days), maximum larval and pupal period (81.83 days) and longest developmental period from egg to adult (98.33 days) whereas, minimum fecundity (47.47 eggs/female), minimum hatching (34.17%), minimum adult survival (30.83%) and maximum longevity of adult male (66.50 days) and female (67.70 days).

Keywords: Temperature, relative humidity, *Rhizopertha dominica* and wheat grains

1. Introduction
Wheat (*Triticum aestivum* L.) is an important cereal crop known to have originated from south western Asia and is a major staple food of world's population [1]. Wheat is attacked by many insect pests in field as well as in storage condition. Although, there are about 200 species of insects and mites found infesting wheat grains, few of which are major or primary pests [16]. Among different stored grain pests, the lesser grain borer, *R. dominica*, is an important internal and primary feeder of various stored wheat grains. *R. dominica*, attacks a wide range of stored cereals such as barley, paddy, wheat, maize and sorghum. It also infests various other commodities including pulses and dried cassava root. With the help of strong jaws it can also damage any part of wooden structure to tide over unfavorable conditions [2]. The beetle is a strong flier, spreads with grater rapidity and is also found attacking wheat in the field [17, 18]. Both the adult and larvae bore into healthy kernels of grain, reducing them to hollow husk by using of their strong mandible. It not only feed on food grains but also affects their nutritional and baking quality as well as germination capacity [3].
A number of workers have suggested use of fumigants and other chemicals to combat with the population of *R. dominica* in the stored grains but toxic chemicals evidently posed several problems, *viz.*, chronic and acute toxicity, development of insect resistance, environmental pollution etc [3, 4, 14]. Therefore, to explore the safer methods with low cost for the management of the pest under question is prime objective of the study. To use bio environmental factors (temperature, humidity etc.) to keep the pest population below economic injury level, it is essential to study various life processes of the pest.
In order to develop economic and effective control measures for *R. dominica*, detailed and accurate knowledge of its bio-ecology is essential under variable macro-ecological conditions which would be helpful in the possible prediction of population levels and study the various mortality factors regulating pest abundance so that an effective management strategy can be developed. These aspects need more intensive investigations, as abiotic factors such as temperature, relative humidity and moisture percentage of stored products play vital role in

pest infestation [4]. Hence, considering the above facts, the present investigations were carried out to study the effect of temperature and relative humidity on the biology of *R. dominica* in stored wheat.

2. Materials and Methods

2.1 Maintenance of insect culture

The nucleus culture of lesser grain borer, *R. dominica* Feb. was obtained from post-harvest Division CTAE, Udaipur, which was further mass multiplied and maintained throughout the experimental period in the laboratory, Department of Entomology, Rajasthan College of Agriculture, on wheat grains (variety Lok-1). The grains were sterilized at 55 ^{0}C for 6 hours in order to eliminate both apparent and hidden infestation of insects and mites, if any [9]. These grains were conditioned at least for a week in an incubator maintaining 28±2 ^{0}C and 60 ± 5 per cent relative humidity to raise their moisture content. These grains were used for mass rearing of the insect using glass jars of 2 liter capacity. The adults so emerged were used for further experimentation.

Biological studies of *R. dominica* was undertaken in the laboratory at five different temperatures of 20 ^{0}C, 25 ^{0}C, 30 ^{0}C, 35 ^{0}C and 40 ^{0}C and five relative humidity levels i.e., 50, 55, 60, 65 and 70 per cent replicated thrice under Completely Randomized Design. These containers were kept in different biological oxygen demand (B.O.D.) incubators which were adjusted at fixed temperature and variable relative humidity. Observations were recorded on fecundity, incubation period, per cent egg hatched, larval + pupal period, developmental period (egg to adult), adult longevity and survival percentage of adult.

2.2 Method of recording observations

For the study of fecundity, 5 pairs of freshly emerged beetles were released in glass vials (15 x 5cm) containing 40 g grains. The total number of eggs laid by the females were counted daily till the death of females. For the incubation period and hatching per cent, 40 freshly laid eggs were placed in small specimen tubes (5 x 1cm) and the observations on time taken for incubation and numbers of eggs hatched were recorded every 12 hours. The duration of larval plus pupal stage was recorded combined, as they spent more periods in grains. The total number of adults emerged, adult longevity, percent survival of adults and total developmental period was recorded. The mean period for complete development was calculated taking the weighted means of the time required for egg, larval and pupal periods. Survival percent of adults was determined by recording the total emergence of adults from pupae.The longevity of male and female adults were determined by recording the dates of their emergence from pupae and the dates of natural death.

3. Results and Discussion

Fecundity

The observation recorded on the effect of temperature, relative humidity and interaction of both the factors on the fecundity of *R. dominica* are presented in Table 1. It is evident from the data that mean number of eggs laid per female on wheat grains was the maximum (217.07 eggs) at 30°C and significant difference in fecundity was recorded. Low (20°C) temperature reduced the fecundity of *R. dominica* to 68.93 eggs which was significantly lower than other levels of temperature and at 40°C temperature females did not lay eggs. The results are in conformity with Pireva [5] who reported that higher fecundity of 384.2 eggs per female at 34 ^{0}C and lowest, 25.8 eggs at 19 ^{0}C and no eggs were laid between 14to 19 ^{0}C and 39 to 42 ^{0}C, respectively [5]. According to Paul [6] female of *R. dominica* laid 244 and 418 eggs at 25 ^{0}C and 34^{0}C temperature, respectively [6]. The average number of eggs laid per female was maximum (185.60) at 70 per cent relative humidity (Table 1). Minimum number of eggs, 145.42 and 154.18 were laid at 50 and 55 per cent relative humidity, respectively. Similarly Rajamma [7] reported that population growth increased with moisture content and were higher at 70-80 per cent relative humidity. The results are in conformity with Navarro *et al.* who reported that the relative humidity was another important factor that, either directly or indirectly influences the development of storage grains insect [8]. The data recorded on the combined effect of temperature and relative humidity (Table 1) revealed that most suitable combination for egg laying was at 30°C temperature and 70 per cent relative humidity on which maximum number of eggs (240.60 eggs/female) were laid; whereas, minimum number of eggs/female (47.47) was at 20°C temperature and 50 per cent relative humidity. The maximum fecundity (307.30/female) and minimum fecundity (60.0/female) was recorded at 30±1 ^{0}C temperature and 75±5 per cent RH and 40±1 ^{0}C temperature and 65±5 per cent RH, respectively [4]. Chander and Bhargava recorded maximum fecundity at 30 ^{0}C and 70 per cent RH [9].

Hatchability (%)

A perusal of Table 2 reveals that the maximum (75.67%) egg hatching was recorded at 30 ^{0}C temperature whereas, minimum (40.51%) egg hatching was recorded at 20 ^{0}C temperature. The egg hatching per cent was recorded (44%) at 21 ^{0}C and maximum (95%) at 34 ^{0}C [5]. Regarding humidity levels the maximum hatching of eggs were recorded at 70 per cent relative humidity, where 70.71 per cent eggs hatched while minimum at 50 per cent relative humidity, where 49.58 per cent eggs hatched. The interaction of temperature and relative humidity on egg hatchability showed that the optimum condition for the egg hatching was 30 ^{0}C temperature and 70 per cent relative humidity, where 87.50 per cent hatching was recorded. Minimum egg hatching per cent (34.17 and 36.67) was recorded at 20 ^{0}C and 50 per cent RH and 20 ^{0}C and 55 per cent relative humidity respectively. According to Kumawat [4] who reported maximum eggs hatching (74.0%) at 30±1 ^{0}C temperature and 75±5 per cent RH and minimum (2.0%) at 40±1 ^{0}C temperature and 65±5 per cent RH. Chander and Bhargava reported that the maximum egg viability at 30 ^{0}C and 70 per cent RH [9].

Incubation period

A perusal of Table 3 revealed that shortest incubation periods (7.91 and 6.40 days) was observed at 35 °C and 30 °C temperature, respectively while the longest incubation periods (14.67 days) was recorded at 20 °C which was statistically different from all temperature levels. According to Mason, the egg stage lasted for about 32 days at 18.1 ^{0}C to 5 days at 36 ^{0}C temperature [11]. Similar trends were also observed in case of relative humidity. Shortest incubation period (7.83 days) was observed at 70 per cent relative humidity (Table 3) whereas, longest 11.00 and 10.42 days, respectively on 50 and 55 per cent relative humidity. The data recoded on the combined effect of temperature and relative humidity presented in Table 3 revealed that the shortest incubation period, 5.33 days was recorded at 35 ^{0}C temperature and 70 per cent relative humidity, whereas the longest duration, 16.50 days was recorded at 20 ^{0}C temperature and 50 per cent

relative humidity. According to Hashem, the duration of egg stage averaged 6.5 days on wheat at 30 ± 1 ^{0}C temperature and 70 ± 5 per cent RH [15]. Faroni reported that the incubation period of *R. dominica* was 6.7 ± 0.1 on wheat at 32 ^{0}C temperature and 80 per cent RH [10].

Larval-pupal period

Data presented in Table 4 reveal that minimum duration for larval and pupal development (36.37 days) was observed at 30°C temperature. Data obtained on the effect of relative humidity on the larval and pupal development (Table 4) revealed that shortest duration of larval plus pupal development (44.25 days) was observed at 70 per cent relative humidity. The longest duration of larval and pupal development, 54.50 days observed at 50 per cent relative humidity. The combined effect of both the factors on the development of larval plus pupal period revealed that shortest period, 31.17 days, was observed at 35 ^{0}C and 70 per cent relative humidity followed by 31.67, 33.83 and 34.17 days, was observed at 30°C and 70 per cent relative humidity, 35 ^{0}C and 65 per cent relative humidity and 30°C and 65 per cent relative humidity, respectively but were statistically at par. Whereas longest duration, 81.83 and 80.17 days, was recorded at 20 ^{0}C temperature with 50 and 55 per cent relative humidity and found statistically at par (Table 4). Hashem reported that the larval stage of *R. dominica* was averaged 19 days, whereas the pre-pupal and pupal stage were averaged one and 6.5 days, respectively on wheat at 30 ± 1 ^{0}C temperature and 70 ± 5 per cent RH [15]. According to Paul [6] at 34 ^{0}C temperature and 70 per cent RH, the larval and pupal stage completed in about 17 and 3 days, respectively [6] while According to Mason, larval development of *R. dominica* usually took 27 to 31 days at 28 ^{0}C and 46 days at 25 ^{0}C temperature and duration of the pupal stage was approximately 5 to 6 days at 28 ^{0}C and 8 days at 25 ^{0}C [11].

Total developmental period (egg to adult stage)

The data on the effect of temperature and relative humidity and interaction of both the factors on the development period of adult have been presented in Table 5 The data revealed that the developmental period of the test insect varied with the temperature levels. The maximum (92.83 days) developmental period was recorded at 20 ^{0}C and minimum (44.28 days) at 30 ^{0}C temperature. The data obtained on the effect of relative humidity revealed that the test insect took 52.09, 54.54 and 56.98 days for completing their development at 70, 65 and 60 per cent relative humidity, respectively but were statistically at par. The developmental period of 61.12 days was recorded at 55 per cent relative humidity followed by 50 per cent relative humidity, where the pest took maximum time (65.50 days) for completing their development. The combined effect of both the factors revealed that the minimum development period of the test insect *i.e.,* 36.50 days was recorded at 35 ^{0}C temperature and 70 per cent relative humidity followed by 38.17 days was recorded at 30 ^{0}C and 70 per cent relative humidity. The maximum developmental period of *R. dominica*, 98.33 days was recorded at temperature 20 ^{0}C and 50 per cent relative humidity. Jagadish *et al.* revealed that the developmental period of *R. dominica* on finger millet from 40 to 50 days with a mean of 44.69 days at 25 ± 1.02 ^{0}C temperature and 70 ± 5.30 per cent RH [12]. According to Astuti *et al*. mean developmental period from egg to adult was 44.67 day at 30 ^{0}C temperature and 70 per cent RH [13].

Survival percentage of adult

The data (Table 6) clearly indicates that the maximum mean per cent adult emergence (63.03) was recorded when insects developed at 30 ^{0}C followed by 53.50, 37.78 and 36.50 per cent at 25 ^{0}C, 35 ^{0}C and 20 ^{0}C, respectively. The most favorable humidity level for adult emergence was 70 per cent, at which maximum adult emergence (56.46%) recorded. At 50 per cent humidity level only 38.54 per cent adults emerged. The combined effect of temperature and relative humidity indicated (Table 6) that the at 30^{0}C and 70 per cent relative humidity maximum 78.83 per cent adults emerged, whereas, at a combination of 20 ^{0}C and 50 per cent relative humidity only 30.83 per cent adults emerged. The results are in conformity with Kumawat [4] reported that maximum and minimum adult survival per cent at 30±1 ^{0}C temperature and 75±5 per cent RH and at 40±1 ^{0}C temperature and 65±5 per cent RH, respectively. Chander and Bhargava reported that maximum adult survival per cent at 30 ^{0}C and 70 per cent RH [9].

Adult longevity

Data on the effect of different temperatures on longevity of adult males and females (Table 7& 8) showed that maximum longevity (64.14 days for male and days 65.66 for female) was recorded at 20 ^{0}C temperature while the minimum (43.48 days for male and 44.64 days for female) was recorded at 35 ^{0}C temperature. The observation recorded on relative humidity revealed that the adult male and female could survive up to 50.12 and 51.23 days, respectively at 70 per cent relative humidity. Maximum adult longevity of 51.43 for male and 53.0 for female were recorded at 50 per cent relative humidity. The combined effect of temperature and relative humidity on the longevity of adult (Table 7& 8) showed that longest survival, up to 66.50 days for male and 67.70 days for female was recorded at 20 ^{0}C temperature and 50 per cent relative humidity, whereas shortest longevity, 40.80 days for male and 42.00 days for female was observed at 35 ^{0}C temperature and 60 per cent relative humidity. The results are in conformity with Jagadish *et al.* reported that female of *R. dominica* lived longer than male [12]. Kumawat reported that the mean female longevity was 30.90 days at 25 ± 1 ^{0}C temperature and 75 ± 5 per cent RH and decreased at higher temperature on wheat [4]. Meenakshi and Srivastava [14] reported that the longevity of adult and found that 34.70 to 55.70 days and 33.0 to 54.10 days for female and male respectively [14].

Table 1: Effect of temperature and relative humidity on fecundity of *R. dominica*

Temperature (0^0C)	Mean number of eggs laid/ female					Mean
	Relative humidity (%)					
	50	55	60	65	70	
20	47.47	59.33	67.13	80.33	90.40	68.93
25	180.33	189.00	195.60	205.33	210.07	196.07
30	191.33	201.07	220.33	232.00	240.60	217.07
35	162.53	167.33	174.27	192.33	201.33	179. 59
40	-	-	-	-	-	-

Mean	145.42	154.18	164.33	177.50	185.60	
		S.Em.±	CD(P=0.05)			
Temp.		3.13	8.65			
RH		3.13	8.65			
Temp x RH		7.00	19.33			

Table 2: Effect of temperature and relative humidity on hatching per cent of *R. dominica*

Per cent egg hatched						
Temperature (0^0C)	**Relative humidity (%)**					**Mean**
	50	55	60	65	70	
20	35.77 (34.17)	37.27 (36.67)	40.00 (39.23)	41.65 (44.17)	44.04 (48.33)	39.53 (40.51)
25	50.28 (59.17)	54.23 (65.83)	55.24 (67.50)	56.79 (70.00)	59.67 (74.50)	55.18 (67.40)
30	51.75 (61.67)	54.74 (66.67)	62.03 (78.00)	66.82 (84.50)	69.30 (87.50)	60.45 (75.67)
35	41.17 (43.33)	43.57 (47.50)	49.31 (57.50)	50.77 (60.00)	58.37 (72.50)	48.54 (56.17)
40	-	-	-	-	-	-
Mean	44.76 (49.58)	47.39 (54.17)	51.09 (60.55)	53.52 (64.67)	56.51 (70.71)	
		S.Em.±	CD (P=0.05)			
Temp.		1.13	3.13			
RH		1.13	3.13			
Temp x RH		2.53	6.99			

Figures in parentheses are retransformed per cent values.

Table 3: Effect of temperature and relative humidity on incubation period of *R. dominica*

Incubation period (days) at						
Temperature (^{0}C)	**Relative humidity (%)**					**Mean**
	50	55	60	65	70	
20	16.50	16.17	14.83	13.83	12.00	14.67
25	10.17	9.83	8.67	7.83	7.50	8.80
30	9.50	8.83	7.89	6.83	6.50	7.91
35	7.83	6.83	6.17	5.83	5.33	6.40
40	-	-	-	-	-	-
Mean	11.00	10.42	9.39	8.58	7.83	
Temp.		S.Em.± 0.15	CD (P=0.05) 0.44			
RH		0.15	0.44			
Temp x RH		0.33	0.98			

Table 4: Effect of temperature and relative humidity on larval plus pupal period of *R. dominica*

Larval plus pupal period (days) at						
Temperature (0^0C)	**Relative humidity (%)**					**Mean**
	50	55	60	65	70	
20	81.83	80.67	78.17	76.17	74.00	78.17
25	45.33	43.83	40.67	39.67	40.17	41.93
30	42.67	37.50	35.86	34.17	31.67	36.37
35	48.17	40.83	35.67	33.83	31.17	37.93
40	-	-	-	-	-	-
Mean	54.50	50.71	47.59	45.96	44.25	
	S.Em.±	CD(P=0.05)				
Temp.	0.73	2.04				
RH	0.73	2.04				
Temp x RH	1.64	4.56				

Table 5: Effect of temperature and relative humidity on development period of *R. dominica*

Egg to adult stage (days) at						
Temperature (0^0C)	**Relative humidity (%)**					**Mean**
	50	55	60	65	70	
20	98.33	96.84	93.00	90.00	86.00	92.83
25	55.50	53.66	49.34	47.50	47.67	50.73
30	52.17	46.33	43.75	41.00	38.17	44.28
35	56.00	47.66	41.84	39.66	36.50	44.33
40						
Mean	65.50	61.12	56.98	54.54	52.09	
	S.Em.±	CD (P=0.05)				
Temp.	0.88	2.44				
RH	0.88	2.44				
Temp x RH	1.97	5.46				

Table 6: Effect of temperature and relative humidity on survival percentage of adult of *R. dominica*

Per cent adult survival at						
Temperature (0^0C)	**Relative humidity (%)**					**Mean**
	50	55	60	65	70	
20	33.73 (30.83)	35.26 (33.33)	37.76 (37.50)	38.75 (39.17)	40.20 (41.67)	37.17 (36.50)
25	44.04 (48.33)	45.48 (50.83)	46.91 (53.33)	48.35 (55.83)	50.28 (59.17)	47.01 (53.50)
30	42.61 (45.83)	46.43 (52.50)	54.03 (65.50)	58.37 (72.50)	62.51 (78.83)	52.55 (63.03)
35	32.69 (29.17)	35.26 (33.33)	37.86 (37.67)	40.69 (42.50)	42.80 (46.17)	37.93 (37.78)
40	-	-	-	-	-	
Mean	38.38 (38.54)	40.69 (42.50)	44.14 (48.50)	46.43 (52.50)	48.71 (56.46)	
	S.Em.±	CD (P=0.05)				
Temp.	0.92	2.55				
RH	0.92	2.55				
Temp x RH	2.06	5.70				

Figures in parentheses are retransformed per cent values.

Table 7: Effect of temperature and relative humidity on adult (male) longevity of *R. dominica*

Longevity of male adult (days)						
Temperature (0^0C)	**Relative humidity (%)**					
	50	**55**	**60**	**65**	**70**	**Mean**
20	66.50	64.40	64.00	62.60	63.20	64.14
25	45.50	46.00	47.90	48.80	51.40	47.92
30	48.50	46.20	43.72	42.60	41.07	44.42
35	45.20	44.80	40.80	41.80	44.80	43.48
40	-	-	-	-	-	-
Mean	51.43	50.35	49.11	48.95	50.12	
	S.Em±	CD(P=0.05)				
Temp.	0.77	2.14				
RH	0.77	2.14				
Temp x RH	1.73	4.79				

Table 8: Effect of temperature and relative humidity on adult (Female) longevity of *R. dominica*

Longevity of female adult (days)						
Temperature (0^0C)	**Relative humidity (%)**					
	50	**55**	**60**	**65**	**70**	**Mean**
20	67.70	65.97	66.00	63.67	64.98	65.66
25	47.18	48.00	49.98	50.87	52.47	49.70
30	50.07	47.23	44.72	43.78	42.37	45.63
35	47.04	46.01	42.00	43.08	45.09	44.64
40	-	-	-	-	-	
Mean	53.00	51.80	50.68	50.35	51.23	
	S.Em.±	CD (P=0.05)				
Temp.	0.80	2.21				
RH	0.80	2.21				
Temp x RH	1.78	4.94				

4. Conclusion

From the present investigation it can be concluded that the combination of 30 °C temperature and 70 per cent relative humidity was most preferred by the insect where maximum fecundity, highest egg hatching per cent and maximum adult survival per cent was recorded. Minimum incubation period, minimum duration of larval and pupal stage and shortest developmental period from egg to adult was recorded at 35 °C temperature and 70 per cent RH and minimum adult longevity of male and female adult was recorded at 35 °C temperature and 60 per cent RH, respectively.

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