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Effect of temperature and humidity on the development and fertility-fecundity of *Aerida exaltata* Walk.

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Abstract. The effect of temperature and humidity on *Acrida exaltata* Walk. has been studied to have two aspects in relation to (i) its effect on hopper development and (ii) its effects on the fertility–fecundity. The rate of development was affected by the moisture present in the environment. No development took place at 0%, 10% and 20% RH. Most desirable range of humidity was between 50–70% RH. Development took place at 20°, 30°, 35° and 40° C in 92·8, 74·8, 71·8 and 66·6 days in males and 101·0, 86·4, 85·6 and 75·2 days in females. Percentage of hoppers reaching the adult stage, longevity of adults, average number of copulation and average number of eggpods per female was influenced by the temperature.

Keywords. Relative humidity ; fertility–fecundity ; development ; copulation ; longevity ; temperature.

1. Introduction

Food consumption was dependent upon the relative humidity (RH) present in the atmosphere and water content in the food (Sanger 1973). Water content of the eggpods directly affects the size of hatchlings in *Schistocerca gregaria*, water loss during the last half of incubation period resulting in smaller hatchlings and excess water uptake in larger hatchlings (Bernays 1972). Shulov (1970) in *Nomadacris septemfasciata* and *Locusta migratoria* found that humidity and temperature affects the development and weight of eggs. Development was arrested when the required moisture was not available, and resumed on being provided with moisture. Petty (1974) in *Locusta migratoria* also found that moisture affects development and hatchling. During developmental period, nymphs preferred higher relative humidity in the field as observed by Riegert (1959). Mathéé (1954) observed in the case of *Locusta pardalina* that viability of eggs was dependent upon the high temperature of the soil. According to Symmons *et al* (1974), temperature range between 30°–40° C was favourable for development. Abou-Elela and Hilmy (1977), Tutkun (1973) and Qayyum and Atique (1973) found that temperature directly influences hatching of eggs, rate of develop-

ment, precopulation, preoviposition period and reproduction. Studies were made to note the effect of temperature and humidity on the hoppers development and fertility-fecundity of *Acrida exaltata* Walk.

2. Material and methods

2.1. *Effect of humidity on hoppers development and fertility-fecundity*

Newly hatched hoppers were kept in jars and glass tubes at 90, 80, 70, 50, 20, 10 and 0% humidity at a constant temperature of 37° C for observations on nymphal duration and fertility-fecundity. Desired relative humidity was obtained through the solution of potassium hydroxide (100 gm of KOH per 100 gm of water) as given by Buxton and Mellanby (1934) (table 1).

2.2. *Effect of temperature on hoppers development and fertility-fecundity*

Newly hatched hoppers were kept individually in glass tubes (15 × 3·8 cm) covered with muslin cloth for observation on hoppers development at 25°, 30°, 35° and 37° C. Nymphs were provided daily with fresh food twice. Standard error was worked out and results are shown in table 2.

Newly emerged adults were kept in pairs at temperature of 20°, 25°, 30°, 35° and 37° C in separate glass jars. Number of copulations and ovipositions was observed and number of eggpods per female and longevity of adults were noted. Results are summarized in table 3.

3. Observations

3.1. *Effect of humidity on the hopper development and fertility-fecundity*

Rate of development of hoppers was affected by moisture present in the environment. No development took place at 0%, 10%, and 20% RH (table 4). The most desirable range of humidity was between 50–70% RH. Percen-

Table 1. Relative humidity obtained through KOH with differing specific gravity.

RH %	gm KOH/100 gm of water	Specific gravity
90	15·0	1·115
80	25·0	1·175
70	35·0	1·265
50	52·0	1·335
20	87·5	1·490
10	110·0	1·570
0	Solid KOH	

Table 2. Effect of temperature on the hoppers development.

Stage		25° C (days)		30° C (days)		35° C (days)		37° C (days)	
		♂	♀	♂	♀	♂	♀	♂	♀
I Instar	Mean	14·40	15·60	11·20	13·80	7·80	9·20	7·20	8·00
	SE	0·81	0·93	0·66	0·86	0·70	0·58	0·37	0·45
II Instar	Mean	14·80	17·80	13·60	12·20	7·60	7·80	6·60	7·20
	SE	0·66	0·86	1·03	0·66	0·61	0·66	0·40	0·58
III Instar	Mean	13·40	15·80	10·80	11·80	8·40	10·40	7·40	8·80
	SE	0·87	0·86	0·58	0·86	0·76	0·68	0·51	0·58
IV Instar	Mean	12·80	15·80	13·80	13·60	9·80	12·20	8·60	10·20
	SE	0·58	0·58	0·86	0·51	0·58	0·66	0·60	0·58
V Instar	Mean	13·60	16·40	12·80	15·80	9·20	11·20	8·40	10·20
	SE	0·51	0·76	0·58	0·80	0·37	0·37	0·51	0·58
VI Instar	Mean	14·80	17·20	14·20	17·40	14·20	16·20	13·40	14·40
	SE	0·37	0·66	0·86	1·03	0·37	0·66	0·60	0·60
VII Instar	Mean	14·20	17·60	14·20	17·00	15·40	18·60	14·00	16·40
	SE	0·37	0·51	0·58	0·74	0·68	1·03	0·55	1·03
Adult	Mean	92·80	101·00	74·80	86·40	71·80	85·60	66·60	75·20
	SE	2·73	2·57	2·17	1·72	0·98	3·02	1·91	2·35
Percentage of hoppers reached adult stage		34·20	31·00	51·50	47·20	73·50	68·00	76·00	71·50

SE = Standard error.

tage of hoppers reaching the adult stage was the highest, 77·86 and 81·25 in males and females respectively at 70% RH, while the lowest, 30·75 and 43·0 in males and females respectively at 90% RH.

As evident from table 2, it was found that at 70% RH, sexual maturation is hastened, but the longevity of adults was shorter, 87 and 116 days in males and females respectively due to the rapid rate of sexual maturation and a high average number of eggs and eggpods per female. As the humidity increased above the optimum (70% RH) the longevity of adults and the time required for sexual maturation increased, but the number of eggs and eggpods per female decreased until 80% RH. Above 80% RH the length of adult life decreased and the number of eggpods were few or none at all. The number of eggpods per female and the number of eggs per pod show a rapid drop at relative humidities below 70% RH.

Table 3. Effect of temperature on fertility-fecundity and longevity of *Acrida exaltata* Walk.

Temperature °C	Sex	No. of pairs	Total mating	Longevity of adults (days) Mean ± SE	Average no. of copulation per male	Average no. of eggpods per female	Average no. of eggs per pod
20	Male Female	5	8	68±2·23 99±2·82	1·6	1	48
25	Male Female	5	14	72±0·55 104±1·57	2·8	2	59
30	Male Female	5	21	78±1·39 113±1·93	4·2	4	76
35	Male Female	5	26	91±1·56 121±2·82	5·2	5	81
37	Male Female	5	28	87±1·59 116±2·95	5·6	7	87

SE = Standard error.

3.2. *Effect of temperature on the hoppers development and fertility-fecundity*

Temperature has a marked influence on the development of hoppers. Rate of development increased at the higher temperatures while at low temperature decreased as is clearly evident from table 2. The total number of mating was increased with the rise in temperature. As shown in table 3, the frequency of copulation, number of eggpods per female and number of eggs per pod increased with the rise in temperature. The temperature range between 30°–37° C was found favourable for copulation, oviposition and number of eggpods per female. Pre-copulation and pre-oviposition period decreased with rise in temperature. Average survival of adults at 35° C was higher than at 25° C. Longevity of adults was 91 and 121 days at 35° C while at 25° C, it was 68 and 99 days in males and females respectively.

4. Discussion

Effect of temperature and humidity on hoppers development must be discussed together, because it is very difficult in experimental work to separate the two factors. On the one hand, the relative humidity of the air varies with temperature, and on the other, hopper metabolism is possibly more affected by the water content of food than by air humidity, both of which may influence the

Table 4. Effect of humidity on hoppers development.

Stage		50% RH		70% RH		80% RH		90% RH	
		♂	♀	♂	♀	♂	♀	♂	♀
		(days)		(days)		(days)		(days)	
I Instar	Mean	8·00	9·80	7·20	8·00	9·80	12·40	15·20	19·20
	SE	0·70	0·73	0·37	0·45	0·73	0·93	0·86	1·28
II Instar	Mean	8·80	10·40	6·60	7·20	11·40	13·20	17·00	20·20
	SE	0·66	0·87	0·40	0·58	0·92	1·06	0·70	1·39
III Instar	Mean	8·40	11·20	7·40	8·80	11·20	12·20	16·40	18·60
	SE	0·50	1·06	0·51	0·58	0·66	0·66	0·76	1·07
IV Instar	Mean	8·40	11·00	8·60	10·20	13·00	13·80	15·60	19·80
	SE	0·76	0·89	0·60	0·58	1·14	1·06	1·07	1·06
V Instar	Mean	9·20	11·20	8·40	10·20	12·80	15·60	18·20	22·20
	SE	0·37	0·66	0·51	0·58	0·58	0·81	0·86	1·24
VI Instar	Mean	12·20	15·60	13·40	14·40	12·80	15·80	16·80	20·80
	SE	0·58	0·92	0·60	0·60	0·86	0·80	0·66	1·42
VII Instar	Mean	13·80	15·80	14·00	16·40	14·80	16·20	15·00	18·80
	SE	0·66	0·66	0·55	1·03	0·86	0·86	1·04	1·15
Adult	Mean	69·60	82·00	66·60	75·00	86·60	91·60	111·00	124·60
	SE	2·22	2·21	1·91	2·35	2·01	2·71	2·35	2·29
Percentage of nymphs reaching adult stage		71·50	73·25	77·86	81·25	58·00	61·25	38·75	43·00

SE = Standard error.

quantity of food consumed and, therefore, the rate of growth. Nevertheless, some evidence of temperature effects should be briefly mentioned. Parker (1930) in his extensive experiments with several American grasshoppers clearly indicated a shortening of hopper period and an accelerated rate of development with rising temperature.

At constant temperature, relative humidity affects the rate of ovarian growth and percentage of hoppers reaching adult stage. These variations in humidity at constant temperature suggest that the different optimal relative humidities and the lower limits are explained by different rates of evaporation (Gunn 1933; Koidsumi 1934) at different temperatures. Zolotarvesky (1933) observed in *Schistocerca gregaria* Forsk. that relative humidity plays a very important role in the embryonic and postembryonic development of locust and grasshopper. The

Table 5. Effect of humidity on fertility-fecundity of *Acrida exaltata* Walk.

Humidity % RH	No. of pairs	Sex	Longevity of adults ± SE	Total mating	Average no. of copulation per male	Average no. of eggpods per female	Average no. of eggs per pod	Hatching %
10	5		No pairing and egg-laying					
20	5		No pairing and egg-laying					
50	5	Male	82·4 ±1·36	25	4·8	5·2	76	71·86
		Female	111·20±0·86					
70	5	Male	87·00±1·56	28	5·6	7·1	85	84·20
		Female	116·00±2·95					
80	5	Male	75·40±1·99	23	3·9	2·6	69	58·40
		Female	105·20±2·23					
90	5	Male	67·40±1·02	14	1·8	1·5	51	21·90
		Female	95·40±1·86					

SE = Standard error.

present findings are contrary to the observations of Husain *et al* (1941) and Chauvin (1941), that relative humidity has no effect on the development of hoppers. However, on examining their results, it was found that they had based their findings on experiments with only a very small number (often only one) of hoppers, and without controlling the moisture of the food. In very detailed and extensive experimental studies on locust by Hamilton (1936, 1950), the effects of a series of combinations of temperatures and relative humidities were studied and it was suggested that the duration of adult life was the shortest when conditions were optimum for sexual maturation and that the length of life gradually increased as conditions became less favourable. In the present observations 70% RH is the optimum for development and sexual maturation. As the relative humidity increased above or decreased below, the time required to reach sexual maturity was increased, but the number of eggpods decreased. This shows that with an increase in the average preoviposition period, an increase in the length of adult life is observed. Similar observations were found by Symmons *et al* (1974) in *Schistocerca gregaria*, that the temperature range between 30°-40° C was favourable for development. Abou-Elela and Hilmy (1977) observed in the case of *Acrotylus insubricus* that temperature has a direct effect on the hatching period and development.

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