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EFFECTS OF TEMPERATURE ON LONGEVITY, FECUNDITY AND FERTILITY OF THE SORGHUM SHOOTFLY, *ATHERIGONA SOCCATA* RONDANI

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Abstract—Effects of temperature on female longevity, fecundity and fertility of the sorghum shootfly, *Atherigona soccata* Rondani, were investigated. The longevity, preoviposition and oviposition periods, eggs per female per day, mean eggs per female and fertility (per cent eggs hatched), for the shootflies maintained at constant temperatures of 20, 25 and 30°C and alternating temperatures of 30°C (photophase) and 20°C (scotophase) referred to as 20–30°C were determined. At lower temperature (20°C), the longevity, preoviposition and oviposition periods were prolonged considerably, while daily egg production, mean fecundity and fertility were decreased. Higher temperature (30°C) had the reverse effect on preoviposition and oviposition periods as well as daily egg production. There was a significant positive correlation between the pupal weight and the number of eggs laid by the fly at 20°C. Egg mortality increased with advance in maternal age. The rate of increase in egg mortality was faster at 30°C than at lower temperatures.

Key Words: *Atherigona soccata*, fecundity, fertility, longevity, egg mortality, sorghum shootfly, temperature

Résumé—Des recherches ont été menées sur les effets de la température sur la longévité, la fécondité et la fertilité des femelles de la mouche du sorgho, *Atherigona soccata* Rondani. Les paramètres suivants ont été évalués chez des femelles élevées sous trois régimes de températures constantes: 20, 25 et 30°C, ainsi qu'en températures alternées de 20°C pendant la scotophase et 30°C pendant la photophase; longévité, durée de la période préreproductrice et de la période reproductrice, nombre d'oeufs par femelle et par jour, nombre moyen d'oeufs par femelle, fertilité (pourcentage d'éclosion). A la température la plus basse (20°C), la longévité ainsi que les périodes préreproductrice et reproductrice sont considérablement allongées, cependant que la production quotidienne d'oeufs, la fécondité et la fertilité moyennes sont réduites. La température la plus élevée (30°C) a l'effet inverse sur les périodes préreproductrice et reproductrice, ainsi que sur la production quotidienne d'oeufs. Il existe une corrélation positive entre le poids nymphal et la nombre d'oeufs pondus par la femelle à 20°C; la mortalité embryonnaire s'accroît avec l'âge de la mère. Le taux d'accroissement de la mortalité embryonnaire est plus élevé à 30°C qu'aux autres températures.

Mots Cléfs: *Atherigona soccata*, fécondité, fertilité, longévité, mortalité embryonnaire, mouche du sorgho, température

INTRODUCTION

The sorghum shootfly, *Atherigona soccata* Rondani (Diptera: Muscidae) is a major pest of sorghum and is widespread throughout the sorghum-growing areas of Africa and Asia (Young and Teetes, 1977; Shie Shiang-Lin *et al.*, 1981). These areas experience a wide range of temperatures. Recent studies have shown that the optimal temperature for preimaginal development of the sorghum shootfly is 30°C (Delobel, 1983). However, information on the relation between temperature, longevity and fecundity of this important pest is limited. Although there are several reports on the longevity and fecundity of the shootflies (Ogwaro, 1978; Meksongsee *et al.*, 1978; Unnithan, 1981; Unnithan and Mathenge, 1983; Raina, 1982), none of these deal with the effects of temperature. The natural rate of increase of the species is dependent on the longevity, fecundity and fertility of the flies, which can in turn be influenced by abiotic factors, such as temperature. It is important, therefore, to understand the effects of temperature on these characteristics of the shootflies. This paper reports our studies on these aspects.

MATERIALS AND METHODS

Experiments were conducted to determine female longevity, fecundity and fertility of the shootflies at constant temperatures of 20, 25 and 30°C and alternating temperatures of 30°C (photophase) and 20°C (scotophase), hereafter referred to as 20–30°C. Shootfly larvae obtained from infested susceptible sorghum [co-ordinate hybrid sorghum-1 (CSH-1)] in the field in Nairobi were maintained as described before (Unnithan and Mathenge, 1983). CSH-1 seedlings were planted in 10.5 × 10 cm plastic pots (five seedlings per pot) and kept in an outdoor cage until they were 2 weeks old. (The CSH-1 seeds were obtained from the Genetic Resources Unit, ICRISAT, Patencheru, Andhra Pradesh, India.) The seedlings were watered regularly and treated with Welgro® liquid fertilizer. When the seedlings were 2 weeks old they were infested artificially with one newly hatched shootfly larva each as described by Delobel (1983), and transferred to environmental chambers set at 12 hr photophase and at four different temperatures: 20, 25 and 30°C constant and alternating temperatures of 30°C (photophase) and 20°C (scotophase; 20–30°C). When pupation occurred, the seedlings were dissected and each pupa weighed and transferred to a glass vial containing moist sterile sand. The pupae were kept in an environmental chamber set at the same temperature at which larval development took place. At emergence, one male and one female fly each were enclosed in a lantern chimney mounted on 10.5 × 10 cm plastic pot containing one CSH-1 seedling and kept in the environmental chamber maintained at temperature and photoperiod corresponding to those used for preimaginal development. The flies were fed on a mixture of baker's yeast and sugar (1:1) and distilled water. Food was changed every day and the seedling every 4–5 days. The flies were observed every morning and the eggs laid were collected from the sorghum seedling with a wet camel hair brush and kept on moist filter paper for hatching. The eggs were incubated at temperatures corresponding to those at which the adults were kept. Hatched eggs were counted 3–4 days later. If the male fly died before the onset of oviposition by the female, a new male was introduced in the chimney to ensure mating.

The parameters considered in the study were: female longevity, preoviposition and oviposition (reproductive) periods, fecundity (eggs per female, eggs per female per day, fecundity range and median fecundity), fertility (per cent eggs hatched), relation between pupal weight and fecundity, and relation between maternal age and egg mortality. For calculating female longevity, half a day was deducted from the period from emergence to the day the fly was found dead. Male longevity was not determined. The data were subjected to the analysis of variance and Duncan's multiple range test, χ^2 test or regression analysis.

RESULTS

Longevity, preoviposition and oviposition periods, fecundity (eggs per female per day, eggs per female, fecundity range and median fecundity), and fertility of shootflies at different temperatures are given in Table 1. In general, higher temperature decreased the longevity (54.9 days at 20°C compared to 26.8 days at 30°C). However, between 20 and 25°C longevity was not significantly different. Similarly at 20–30 and 30°C also there was no significant difference in longevity. Survival rates of shootfly females at different temperatures tested are shown in Fig. 1. At 30 and 20–30°C less than 50% of the flies survived for more than 30 days, whereas over 50% survived for 45 days or more at 25 and 20°C. Maximum longevity recorded was 107 at 20°C, 97 at 25°C, 86 at 20–30°C and 62 days at 30°C.

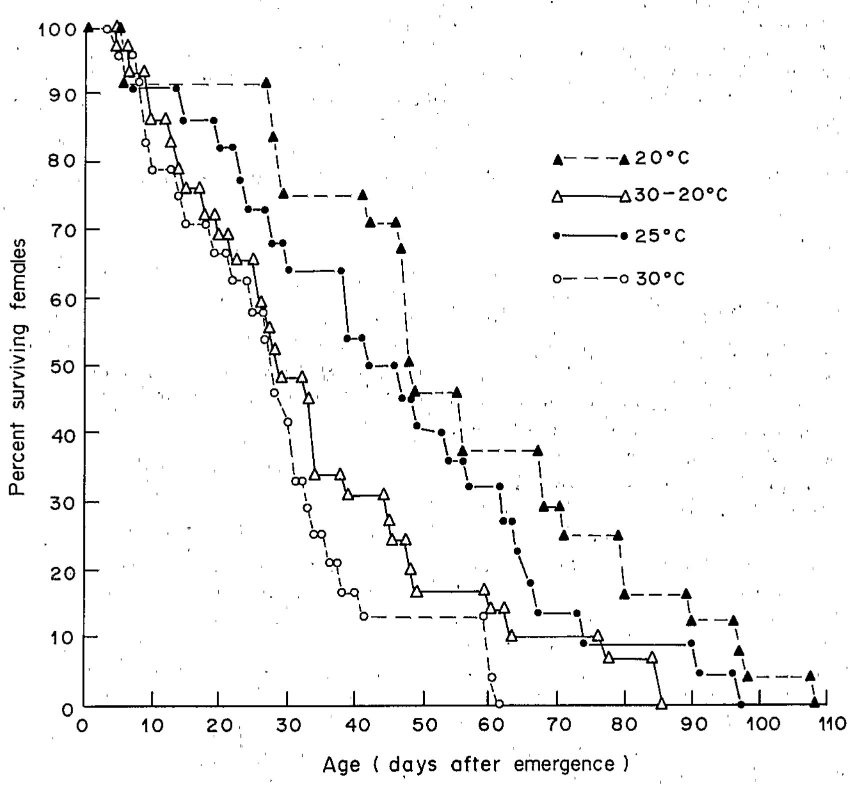

Fig. 1. Survival curve of sorghum shootfly females at 20, 25, 30 and 20–30°C.

Table 1. Longevity, fecundity and fertility of sorghum shootflies at different temperatures

Temperature (°C)	Number of insects	Female longevity (mean, days)	Preoviposition period (mean, days)	Oviposition period (mean, days)	Eggs per female per day (mean)	Eggs per female (geometric mean)	Per cent eggs hatched
20	24	54.9[a]	7.3[a]	47.8[a]	3.1	83.8[b] (154; 0–682)	63.2[a]
25	22	45.0[ac]	3.8[b]	38.4[ac]	6.2	212.0[a] (239; 21–624)	—
20–30	29	34.1[bc]	3.9[b]	30.4[bc]	6.6	175.0[ab] (223; 26–584)	83.2[b]
30	24	26.8[b]	3.6[b]	26.0[b]	9.4	154.5[ab] (234; 0–715)	68.6[c]
		($F = 6.67$) ($P < 0.01$)	($F = 9.03$) ($P < 0.01$)	($F = 5.81$) ($P < 0.05$)		($F = 2.32$) ($P < 0.05$)	($P < 0.001$)

Means and percentages followed by the same letter are not significantly different from each other. Figures in parentheses represent median fecundity and fecundity range. — = Hatching not determined.

Preoviposition and oviposition periods were prolonged at lower temperatures (Table 1). Preoviposition period increased from 3.6 days at 30°C to 7.3 days at 20°C. After the flies ceased to be reproductively active they survived for an average of 7.1, 6.6, 3.7 and 0.8 days, respectively at 20, 25, 20–30 and 30°C. Daily egg production (eggs per female per day) increased at higher temperature. On average 9.4 eggs were laid per day at 30°C compared to 3.1 at 20°C. At 25°C and above, more than 50% of the total eggs were laid in less than 16 days after emergence. Mean and median fecundities were also lowest at 20°C. Mean number of eggs laid were 83.8, 212, 175 and 154 at 20, 25, 20–30 and 30°C, respectively (Table 1). Mean fecundities were significantly different from each other only at 20 and 25°C. Maximum number of eggs laid by a single fly was 715 which was at 30°C. At 20 and 30°C some flies died a few days after emergence before laying any eggs.

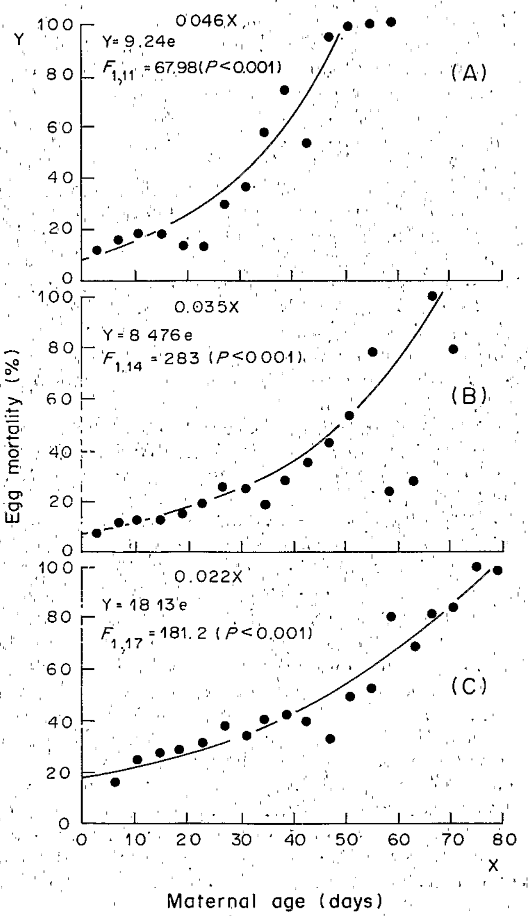

Fig. 2. Relation between maternal age and egg mortality in the sorghum shootfly (A) at 30°C; (B) at 20–30°C; (C) at 20°C.

Pupal weight (mg, mean ± SE) of flies used for fecundity studies at 20, 25, 20–30 and 30°C were 5.8 ± 0.2, 5.6 ± 0.2, 6.1 ± 0.3 and 5.9 ± 0.3, respectively. There was no correlation between mean fecundity and mean pupal weight. However, at 20°C heavier females laid more eggs and there was a significant positive correlation between pupal weight and number of eggs laid ($r = 0.57$, $P < 0.01$).

Temperature also affected the fertility of the shootflies. At 20–30°C 83.2% of the eggs hatched compared to 63.2% at 20°C and 68.6% at 30°C; the differences were highly significant. Fertility was also influenced by maternal age. The number of unhatched eggs (egg mortality) increased with advanced maternal age (Fig. 2). Some of the unhatched eggs did not show any sign of embryonic development indicating that they were not fertilized. Older females also laid eggs which sometimes dried up soon after they were laid; these eggs appeared to be 'empty'. There was a significant positive correlation between increase in egg mortality and increase in maternal age (Fig. 2). The rate of increase in mortality (infertility) was faster at 30 than at 20 or 20–30°C.

DISCUSSION

Like preimaginal development, adult survival and reproduction of the shootfly were also affected by temperature. In general, adult longevity was shortened as the temperature increased. Longevity at 30°C was reduced to half that at 20°C. Almost all the aspects of reproduction such as the onset oviposition, number of eggs laid, duration of reproductive period as well as fertility were affected by temperature. The lowest temperature used in this study (20°C) delayed oviposition, prolonged the reproductive period and reduced the daily and total number of eggs produced as well as fertility, while higher temperature (30°C) had the reverse effect on preoviposition and oviposition periods as well as daily egg production. Fertility was, however, higher at lower temperatures (20–30°C) than at higher temperatures (30°C). Although longevity decreased as the temperature increased there was no corresponding decrease in fecundity, because of the increase in daily egg production. A comparison of longevity, reproductive period and fecundity at 25°C constant and 20–30°C (average 25°C) shows that higher temperature even for part of the day (photophase), had decreased the longevity and increased daily production of eggs. Mean fecundity was highest at medium temperature (25°C). At 15°C or below, shootflies do not lay any eggs (Delobel and Unnithan, 1983).

The effects of temperature on shootfly longevity and fecundity appear to be influenced by other factors such as adult diet. In earlier studies on shootfly fecundity at 30°C, flies fed on brewer's yeast and glucose had longevities of 17.6 (Unnithan, 1981) and 17.1 days (Raina, 1982), compared to 26.8 days for flies fed on baker's yeast and sugar in the present study. Similarly, fecundity was also lower when the flies were fed on brewer's yeast and glucose (Unnithan, 1981; Raina, 1982), instead of the diet used in the present study.

No correlation between pupal weight and fecundity was revealed except at 20°C where heavier adults laid more eggs. Fertility was highest at 20–30°C and infertility (egg mortality) increased with increasing maternal age. It appears that this influence of maternal age on egg mortality is dependent on temperature as the increase in mortality rate was faster at 30°C. As the shootfly females mate only once (Unnithan, unpublished), the sperms stored in the spermathecae might have depleted in older females and this probably led to the production of infertile eggs. Perhaps, the very low and very high temperatures (20 and 30°C) also might have affected the viable life of the sperms stored in the spermathecae.

Similar effects of temperature on longevity and fecundity of the shootflies were also reported for other insects like the onion maggot (*Hylemya antiqua*; Robinson and Zurlini, 1979) and the Mexican bean beetle (*Epilachna varivestis*; Kitayama *et al.*, 1979). But, in the Mediterranean fruitfly, *Ceratitis capitata*, preoviposition period was increased from 5 days at 25°C to 9 days at 30°C (Shoukry and Hafeez, 1974). Previous studies have shown great differences in shootfly fecundity, 20–25 (Kundu and Kishore, 1970), 29 (Sukhani and Jotwani, 1979), 62.8 (Ogwaro, 1978), 234 (Meksongsee *et al.*, 1979), 74 (Unnithan, 1981), 107 (Shie Shiang-Lin *et al.*, 1981), 202 (Unnithan and Mathenge, 1983) and 78.4 (Raina, 1982). These differences appear to be mainly due to varying experimental conditions, particularly adult diet and rearing temperature. The present study confirms that under suitable conditions, the reproductive potential of the shootfly is considerably higher than what was suggested by earlier studies.

Temperature is a major determinant factor in the rate of increase in the natural population of shootflies. The lower and upper threshold for shootfly population increase have been determined to be 16.3°C and slightly above 30°C, respectively (Delobel and Unnithan, 1983). In this connection it is interesting to note that the mean monthly temperature at Mbita Point Field Station, which is located in a major sorghum-growing area, range from 23.9°C in June to 25.5°C in October. As far as temperature is concerned this area is extremely suitable for the shootfly development throughout the year. However, there are other limiting factors like humidity and availability of host plants which affects shootfly reproduction and population increase.

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