Rainfall as a mortality factor in the Sorghum Shootfly, *Atherigona soccata* Rond. (Diptera, Muscidae)

By A. G. L. Delobel and M. C. Lubega

Abstract

The effect of rain on insect survival is difficult to demonstrate with direct sampling techniques, specially in the adult stage. Observations were made in a sorghum field in Nairobi during the 1981 main rainy season, using yellow water pan traps, and data were examined using multiple regression analysis. Results indicate that rains, and more particularly heavy falls of rain occurring at the beginning of the rainy season, cause a substantial mortality among adults of the sorghum shootfly (*Atherigona soccata* Rondàni). Rain does not adversely affect the survival of sorghum shootfly eggs, which are protected on the lower surface of leaves.

1 Introduction

Information on the direct influence of excessive precipitation on insect survival is scanty because precise data are difficult to obtain; rain has however been shown to cause the death of a wide variety of insects, in the preimaginal as well as adult stages: several aphid species (Varley et al. 1973, Hughes 1963, Maelzer 1977), the European corn borer *Ostrinia nubilalis* (Sappington and Showers 1983), the Australian bushfly *Musca vetustissima* (Hughes 1979), the screwworm *Cochliomyia americana* (Parman 1945). It is also known that insect eggs may be washed away by rain or wind (Wood 1965).

Taksdal and Baliddawa (1975) in Uganda found a strong correlation between infestation levels by the sorghum shoot fly (*Atherigona soccata* Rondani) and low rainfall; they reported that high precipitations lowered trap catches, but it was not clear to them whether this was due to a higher adult mortality or to a reduction in trap efficiency. On the other hand, some authors (Clearwater and Othieno 1977, Ogwaro 1979, Meksongsee et al. 1981) consider that rainfall triggers a synchronous emergence of adults.

A. soccata is mainly harmful to sorghum seedlings during a few weeks after germination (Young and Teetes 1977, Young 1981, Delobel 1982). As noted by Cobley and Steele (1976), because sorghum is often the staple food crop in African and Asian savannas, it is usually given priority over other crops and is therefore sown very early, with the first rains of the season. Moreover, its ability to withstand limited dry spells, even as a seedling, makes sorghum a choice crop in regions with erratic precipitations at planting time. In theses areas, rainfall is indeed a major element to consider for the explanation of population fluctuations of the sorghum shoot fly.

Preliminary oberservations in sorghum fields at Icipe Mbita Point Field Station and in Nairobi had indicated that heavy rains were often immediately followed by periods of low shootfly infestation. Experiments were therefore conducted with a view to assessing the possible negative effect of rain on

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survival of eggs and adults, which are the only unprotected stages in the life cycle of the shoot fly (larval and pupal development takes place inside the host plant).

2 Material and methods

Experiments were conducted during 1979–81 in an isolated sorghum field in Nairobi. A plot of highly susceptible Indian sorghum (hybrid CSH-1) was planted in 1979, and afterwards regularly ratooned an irrigated in order to maintain a satisfactory growth of tillers; as a result, shootfly populations bred throughout the year without interruption. Although very little sorghum was grown in the vicinity of the study site, a local population of *A. soccata* was present on *Sorghum arundinaceum*, which is a common wild host of the sorghum shoot fly in Kenya (DELOBEL and UNNITHAN 1981).

Adult populations of *A. soccata* were monitored by means of four canary yellow water pan traps (33.2 cm in diameter, 4.2 cm deep) operated on Mondays and Tuesdays for a period of 35 weeks before, during and after the 1981 main rainy season. Canary yellow was found to be the most attractive colour in a separate experiment where eight different colours were tested. Adult numbers were transformed using the log (n+1) transformation. Shoot fly adults were identified using CLEARWATER's (1981) indentification methods. From the observation on the fat body and on the corpus luteum, females were distributed into two age groups: nulliparous and multiparous flies. Temperature of the air 25 cm above soil level and inside a sorghum shoot was recorded every hour by a Grant Multichannel Recorder. Single und mulitple linear regression analyses were performed by means of the least squares method with regard to independent factors with possible effect on trap efficiency (daily sunshine hours, rainfall and mean daily air temperature during trapping periods) and to factors with possible influence on shootfly population levels (rainfall during the week before trapping, number of sorghum shoots at a susceptible stage present in the field, mean weekly temperature in the sorghum shoot). The rate of parasitism by the larval parasite *Tetrastichus nyemitawus* Rohwer was assessed every week by collecting varying numbers of third instar larvae from infested shoots and rearing them in the laboratory until adult or parasite emergence.

To assess egg mortality in the relation to rain, gravid females were allowed to oviposit on 100 potted sorghum seedlings for two hours. Plants were left in the field until eggs had hatched (two to four days). Eggs were counted before and after their transfer to the field; those which were not recovered were considered, either to haven been washed away by rain, or eaten by predators. This was repated 15 times at one month intervals from March 1979 to May 1980. The relationship between percentage of disappeared eggs (transformed using the $\sin^{-1}\sqrt{p}$ transformation) and precipitation during the exposure in the field was examined using linear regression analysis. The possible effect of parasitism by the Chalcid *Trichogramma kalkae* Schulten and Feijen was assessed by collecting every week one hundred freshly laid eggs, which were incubated at 30 °C.

3 Results

The number of trapped adults, which was slowly declining in February and March, dropped immediately after the first major rain (47 mm on March 21st) of the 1981 long rains (fig. 1), and dead flies were found drowned in sorghum leaf whorls shortly afterwards. Males and females were equally affected. Only nulliparous females were caught during the first five weeks after the onset of rains; as preoviposition period is less than 3 to 8 days (UNNITHAN 1981), it is reasonable to assume that these flies were recently emerged. Fly numbers slowly increased throughout the rainy season, then more rapidly during the dry period which followed. A heavy rain at the end of August had a similar depressing effect on trap catches. Weather conditions influenced trap efficiency, as reflected by single linear regression coefficients relating trap catches to meteorological data during trapping periods: a slight but significant positive correlation ($R = 0.39$; $P < 0.05$) was found between the number of adults caught and the number of sunshine hours on corresponding Mondays and Tuesdays. The amount of rainfall during trapping days adversely affected trap

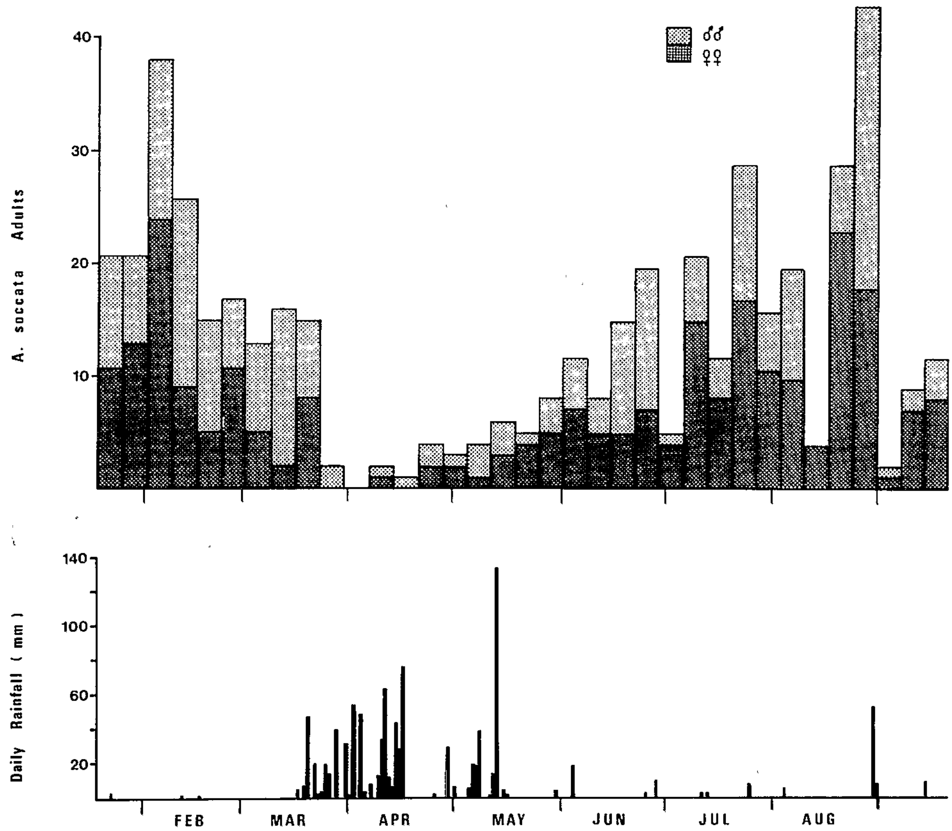

Fig. 1. Effect of rain on *A. soccata* adult populations; number ob adults caught in yellow water pan traps (Nairobi, January to September, 1981) and daily rainfall pattern for the same period

catch ($R = -0.53$; $P < 0.01$). Mean daily temperature during trapping, however, had no effect on trap efficiency ($R = 0.03$). Among the variates tested for their possible influence on shoot fly populations, the number of susceptible shoots present in the field one generation earlier (that is six to ten weeks at a mean temperature of 15 to 20 °C), was not correlated with trap catch; this indicated that competition between first instar larvae for the available shoots never reached a significant level. The mean weekly air temperature was also not significantly correlated with trap catch. But the correlation between precipitation during the week preceeding the two trapping days and trap catch was strong and negative ($R = -0.67$; $P < 0.001$), and this last factor was the single most important one affecting catches (fig. 2). The best linear regression equation, identified by the "all possible regressions" method (DRAPER and SMITH 1966) and combining three of the seven variates initially considered was

$$Y = 1.767 - 0.003X_1 - 0.026X_2 + 0.024X_3,$$

where Y represented the logarithm of the number of shoot flies caught in two days; X_1, the amount of rainfall (in mm) during the week before the trapping

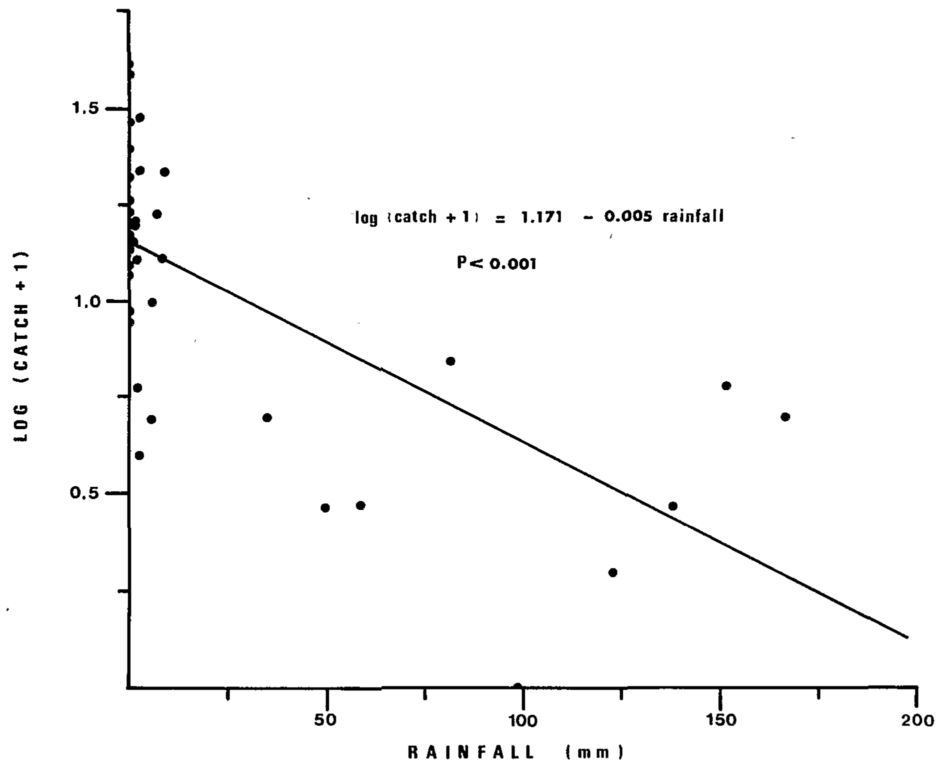

Fig. 2. Catches of *A. soccata* as a function of the amount of rain during the week preceding trapping days

days; X_2, the amount of rainfall during trapping days; and X_3, the number of sunshine hours during trapping. The overall correlation coefficient was $R = 0.781$ ($P < 0.001$); 61 % of the variance was explained by the fitted equation.

Egg prasitism by *T. kalkae* in 1981 remained below 3 %, except on one occasion (end of August), when it reached 5.8 %. Larval parasitism by *T. nyemitawus* remained less than 10 % until the end of the rains in May, when it reached a peak of 28.6 %, then decreased; another peak (30.3 %) was observed in the first half of September.

The following predators of shootfly eggs were identified; a mite, probably related to the *Abrolophus* sp. which feeds on *A. soccata* eggs in India (SESHU REDDY and DAVIES 1978); a coccinellid beetle, *Scymnus trepidulus* Wiese, which is also an active predator of various aphids; several species of unidentified spiders. These predators either sucked the egg contents without breaking the chorion (in the case of the predatory mite) or left more or less conspicuous remnants of the chorion attached to the leaf surface (in the case of spiders and of *S. trepidulus*). The proportion of eggs which had been preyed upon during the exposure of seedlings was therefore assumed to be known with a reasonable degree of accuracy; it ranged from 5.8 to 67.0 % during the study. The correlation between the amount to rain and the number of unrecovered eggs after the same period of time was not significant ($R = 0.08$), indicating that rain had no direct effect on egg mortality.

4 Discussion

In spite of the presence around the study site of a "wild" shoot fly population of unknown size, our data show a significant correlation between rainfall and decrease in adult numbers; a loss in trap efficiency due to reduced sunshine and possibly to an arrestant effect of rain (MILES 1951, BARDNER et al. 1968), also occurred.

We cannot exclude the possibility of an indirect action of rain on the survival of preimaginal and adult stages; this is however largely ruled out by the fact that no adult mortality due to fungal infection was noted, no increase in egg or larval mortality detected; in particular, egg and larval parasitism remained too low or occurred too long after the rains to have any marked effect on adult populations. An increased pupal mortality remains a possibility, although there is no evidence of an adverse effect of rain on pupal survival; as pupation usually takes place in the base of the sorghum shoot (SRIVASTAVA and SINGH 1973), pupae are well protected from the mechanical effect of rains. Also, had rain affected one of the preimaginal stages rather than the adult stage, adult numbers would have decreased progressively, without marked reduction after the onset of rains, as adult longevity exceeds two (UNNITHAN 1981) or even seven (SHIE SHIANG-LIN et al. 1981) weeks in the laboratory.

Evidence from these investigations strongly suggests that heavy rain falls destroy part of the existing adult shoot fly population. From a few casual oberservations, it may be assumed that some of the flies drown while finding shelter in the sorghum whorls. It is apparent from a detailed analysis of the age structure of the same shootfly population (DELOBEL and UNNITHAN 1983) that mortality on older flies is higher than expected, probably because of a lower resistance to adverse conditions, and in particular to rain. This is the reason why a heavy fall of rain in mid-May was not followed by a distinct fall in numbers of the shoot fly: at that time of the year most flies were recently emerged, and were therfore less affected by rain than would have been older flies.

The major mortality factor in the egg stage appears to be predation. Sorghum shootfly egg survival is not affected by rain because the position of eggs on the lower surface of leaves protects them from normal precipitations. However, the maximum daily rainfall during the experiment was 82 mm only, and the effect of more intense rains remains unknown.

It has often been stated that an increase in shootfly populations occurred after the onset of the rainy season. Rains are assumed to trigger a synchronous emergence of adults, either by breaking a larval (CLEARWATER and OTHIENO 1977) or pupal (OGWARO 1979) diapause, or because successful emergence of the flies requires a certain level of soil humidity (TAKSDAL and BALIDDAWA 1975). It has been recently shown that diapause does not occur under East African conditions (DELOBEL and UNNITHAN 1981), and that normal falls of rain act on populations of the shootfly through their effects on the development of the host plant rather than by breaking a diapause. It must be emphasized that the infestation build-up observed after the onset of rains by serveral authors is the result of favourable climatic conditions and of the numerical increase of susceptible sorghum shoots, not of synchronous adult emergences. Moreover, the peak of adult emergence always follows the rains with a delay of several weeks or even a few months (see JOTWANI et al. 1970, BONZI 1981), and often takes place in the midst of the dry season (see TAKSDAL and BALIDDAWA 1975). The fluctuation of adult numbers observed in Nairobi in 1981 does not depart from this rule. It also reveals that rains may, under given circumstances and by direct mechanical action, further delay the evolution of shootfly infestations.

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Zusammenfassung

Regen als Mortalitätsfaktor bei der Sorghum-Fliege, Atherigona soccata Rond. (Dipt., Muscidae)

Die Wirkung des Regens auf das Überleben von Insekten ist mit Sammelmethoden schwer zu belegen, besonders was die Adulten betrifft. Es wurden Untersuchungen in einem Sorghum-Feld bei Nairobi während der Regenzeit 1981 unter Verwendung gelber Wasserschalen-Fallen durchgeführt. Die Ergebnisse wurden der multiplen Regressionsanalyse unterzogen. Sie zeigen, daß Regenfälle, vor allem stärkere Niederschläge zu Beginn der Regenzeit, bei den adulten Sorghum-Fliegen beträchtliche Sterblichkeit hervorrufen. Dagegen wirken sie sich für die geschützt an die Blattunterseiten abgelegten Eier nicht nachteilig aus.

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