*Ent. exp. & appl.* 31 (1982) 170—174. *Ned. Entomol. Ver. Amsterdam*

# EFFECTS OF SORGHUM DENSITY ON OVIPOSITION AND SURVIVAL OF THE SORGHUM SHOOT FLY, *ATHERIGONA SOCCATA*

ALEX G. L. DELOBEL

O.R.S.T.O.M. Scientist, The International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya

The effect of six different plant densities of sorghum on oviposition by *Atherigona soccata* was assessed by counting eggs 19 days after emergence of the crop. In low density plots (22 plants/m$^2$), plants received 3.35 times more eggs than plants in the densest plots (704 plants/m$^2$). In terms of egg density per unit area, the increase in plant density fitted the regression equation $y = ax^b$ at lower densities, and $y = a + b \text{ Log } x$ at higher densities. The relationship between plant density and oviposition is explained by the interaction of the deterring effect of an excess of vegetation with the non-attractiveness of plants grown at excessive densities. Larval mortality resulting from competition increased from high to low plant density.

KEY WORDS: *Atherigona soccata* — Sorghum shoot fly, *Sorghum bicolor* — Plant density.

In most of the semi-arid tropics of the Old World, little or no insecticide is used for insect control in cereal crops. The sorghum shootfly, *Atherigona soccata* Rondani, attacks seedling sorghum and control is difficult because larval development occurs under the protection of the plant tissues. Such control methods as adjustment of the date of planting (Shri Ram *et al.*, 1976; Lingegowda *et al.*, 1972; Janardhanarao *et al.*, 1971), intercropping with maize or legumes, and adult trapping (Meksongsee *et al.*, 1981) have been advocated. The use of higher seeding rates and thinning of infested plants is also an effective control practice (Ponnaiya, 1951; Young, 1981). This method is based on the fact that *A. soccata* eggs are laid randomly (Delobel, 1981) and that a sorghum shoot can sustain only a single first instar larva (Meksongsee *et al.*, 1981). The effect of various plant densities on oviposition and survival of the sorghum shoot fly is reported here.

## MATERIALS AND METHODS

The study was conducted at ICIPE Mbita Point Field Station near Lake Victoria (South Nyanza Province, Kenya). Six different plant densities were replicated 4 times in 3 × 3 m plots, in randomized blocks. Sorghum, variety Serena, was sown on November 11, 1980, during the short rainy season. Rows were 30 cm apart and hills 15 cm (for the lowest density) and 7.5 cm (higher densities) apart. Densities from 22 to 704 plants/m$^2$ were obtained by increasing the number of seeds per hill.

Nineteen days after crop emergence, *A. soccata* eggs were counted on 230 seedlings taken at random from each plot. In order to detect the possible existence of a border effect, each plot was divided in 2 parts of equivalent area; the exterior one comprised 2 complete rows on 2 opposite sides and 2 hills at the end of each row on the other sides. Eggs were recorded separately from the 2 parts.

Three criteria were used to compare the growth of plants under the five higher densities: stem height, measured from the collar to the ligule of the last expanded leaf; maximum width of the last expanded leaf; and leaf stage (number of completely expanded leaves). These measurements were taken from 30 plants at each density.

To determine the effect of different plant densities on oviposition by female sorghum shoot flies, the regressions of plant density on number of eggs per plant and per m$^2$ were calculated.

Four simple models were used: (1) $y = ax + b$ (linear); (2) $y = ax^b$ (power); (3) $y = a + b \text{ Log } x$ (logarithmic); (4) $y = ae^{bx}$ (exponential), where $y$ = number of eggs per plant or per m$^2$ and $x$ = plant density. Coefficients a and b were calculated for the equations which gave the best fit to the curve and the best correlation coefficient.

## RESULTS

*Plant growth and development.* Stem length of

TABLE I

*Characteristics of sorghum seedlings at different densities (means of 30 plants ± S.D.). Means followed by the same letter in the same line do not differ significantly at P = 0.05*

| Plant density (Seedlings/m$^2$) | 44 | 88 | 176 | 352 | 704 |
|---|---|---|---|---|---|
| Stem height (cm) | 10.4$^a$ ± 0.23 | 11.8$^b$ ± 0.26 | 12.1$^b$ ± 0.28 | 16.4$^d$ ± 0.38 | 13.5$^c$ ± 0.42 |
| Width of last expanded leaf (mm) | 32.8$^a$ ± 1.02 | 29.1$^b$ ± 1.32 | 23.2$^c$ ± 1.37 | 25.4$^c$ ± 0.49 | 18.8$^d$ ± 0.90 |
| Leaf stage | 6.1$^a$ ± 0.10 | 6.0$^a$ ± 0.10 | 5.7$^{ab}$ ± 0.09 | 5.9$^a$ ± 0.08 | 5.4$^b$ ± 0.11 |

plants increased in plots planted from a density of 44 plants/m$^2$ to 352 plants/m$^2$, but was slightly shorter at the maximum density of 704 plants/m$^2$ (Table I). Leaf width generally decreased from the lowest to the highest density and little difference existed in leaf stage, except plants in the most dense plots had fewer leaves.

In general, plants in low density plots were stouter, with broader and greener leaves, while plants in high density plots tended to be weaker and more yellowish in colour.

*Border effect.* A Chi-square test of heterogeneity (Goulden, 1969) was performed in order to compare the number of eggs per plant between the interior and exterior parts of the plots. No heterogeneity could be detected among the different replications with regards to border effect ($\chi^2 < 3.9$, d.f. = 3, N.S.). A border effect existed only at the highest density of 704 plants per m$^2$ ($\chi^2 = 10.3$, d.f. = 1, $P < 0.05$). At this density, plants growing along the edges received 1.5 times more eggs than those located in the interior part of the plots. Consequently, for the rest of the study, plants growing along the edges have been disregarded.

*Egg density.* Egg counts in the individual plots have been subjected to analysis of variance. The results did not show any difference in egg numbers between blocks (F = 1.4, d.f. = 3/15, N.S.), but revealed highly significant differences between densities (F = 8.5, d.f. = 5/15, $P < 0.001$), indicating that oviposition is influenced by plant density.

The mean number of eggs laid on plants at each of the six densities is shown in Fig. 1A. Data fitted the curve generated by the regression equation $y = 1.68\ x^{-0.34}$, with a coefficient of determination $r^2 = 0.88$ ($r = 0.94$).

The corresponding number of eggs per unit area is shown in Fig. 1B. At lower densities, data fitted best the curve generated by equation $y = 1.68\ x^{0.66}$ ($r^2 = 0.97$ for all data; $r = 0.98$), whereas at higher densities ($D > 120$), they fitted more closely the curve generated by the regression equation $y = 28.71 \text{ Log } x - 84.81$ ($r^2 = 0.97$).

TABLE II

*Mortality of* A. soccata *first instar larvae due to intra specific competition at different plant densities*

| Plant density (Seedlings/m$^2$) | 22 | 44 | 88 | 176 | 352 | 704 |
|---|---|---|---|---|---|---|
| Total number of eggs | 237 | 193 | 168 | 157 | 95 | 64 |
| No. supernumerary eggs | 45 | 29 | 21 | 23 | 6 | 4 |
| Mortality due to competition (%) | 18.9 | 15.0 | 12.5 | 14.6 | 6.3 | 6.2 |

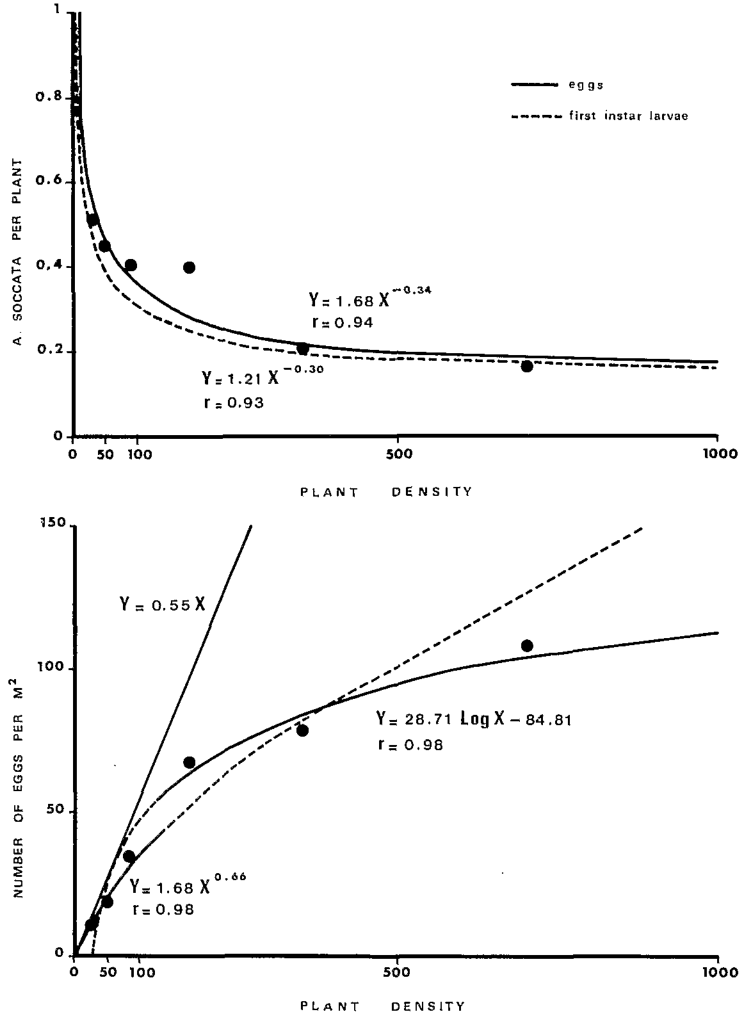


Fig. 1. Relationship between host-plant density and (A) number of *A. soccata* eggs and surviving first instar larvae per plant, (B) number of *A. soccata* eggs per unit area. Mbita Point Field Station, 1980.

*Larval mortality.* In many instances, more than one egg was found on a single plant. The number of supernumerary eggs observed at each plant density, as shown in Table II, decreased regularly from low to high density plots. As a consequence, the mortality which may be expected to occur among newly hatched larvae as a result of the fact that a sorghum shoot can sustain a single first instar larva only, decreased from low to high densities; it was 18.9% at a density of 22 plants/m$^2$ but only 6.2% at a density of 704 plants/m$^2$.

## DISCUSSION

Individual sorghum plants received the greatest number of shootfly eggs per plant in plots of low plant density (Fig. 1A), with plants at the lowest density receiving 3.35 times more eggs than plants at the highest density. The relationship between plant density and number of eggs per plant can be expressed as

$$E = a D^b \qquad (1)$$

where E is the number of eggs per plant and D the plant density.

The straight line in Fig. 1B shows the theoretical effect of increasing plant density on egg density, assuming flies laid the same number of eggs (equal here to the mean number of eggs collected in all plots) on each plant, irrespective of plant density. The observed data depart very early from this theoretical line, at densities as low as 55 plants/m$^2$. The actual relationship between plant density and number of eggs per unit area (egg density, ED) can be expressed as

$$ED = a D^{b+1} \quad (2)$$

at lower densities and

$$ED = a' + b' \text{Log } D \quad (3)$$

where Log is a napierian logarithm, at higher plant densities. There is agreement with the observations of Finch & Skinner (1976) on eggs of *Erioischia brassicae* (Bouché), the cabbage rootfly, at different densities of its host plant, cauliflower. However, the authors did not explore plant densities higher than 80 plants per $m^2$. The departure from equation (2) at high plant densities in the case of *A. soccata* may be explained by the conjunction of two phenomena: the detrimental effect of high densities on plant attractiveness, shown earlier, and the reduction of oviposition due to an excess of vegetation. The fact that a border effect exists only at the highest density indicates that the latter phenomenon occurs only at densities higher than 352 plants/$m^2$.

The theoretical curve of *A. soccata* first instar numbers (assuming that all newly hatched larvae, except the supernumerary ones, survived) is shown in Fig. 1. Its equation is $Y = 1.21\, x^{-0.30}$ ($r^2 = 0.87$) and it differs from the curve giving the number of eggs per plant as a function of plant density mainly in that it has an intercept of 1.21, which is in close agreement with the theoretical value of one larva per plant.

Fig. 1A shows that, while the number of newly hatched larvae decreases with increasing plant density, little gain is obtained at densities higher than 100 plants/$m^2$; at that particular density, the mean number of larvae per plant would lie 0.30, while at a density of 1000 plants/$m^2$, it would be 0.15. On the contrary, the mean number of *A. soccata* larvae per plant increases very rapidly when plant density decreases from about 50 to zero. Therefore, the ideal density (a low plant density with a reasonably low number of larvae per plant) would lie around 50 plants/$m^2$. Such a density, while it would produce a rather low rate of infestation (about 0.38 insects per plant in the present case), would not give a satisfactory yield. The removal of infested seedlings at a time when plants have passed the susceptible stage, that is when their height exceeds 22 cm (Delobel, *in litt.*) could prove, at least under relatively low population levels, to be a satisfactory control method.

I thank Dr. A. K. Raina, Research Scientist at ICIPE, Nairobi, for comments and Mr. P. Ollimo, Mbita Point Field Station, for technical assistance. Supported by Délégation Générale à la Recherche Scientifique et Technique (France) Grant No. 78 7 0896.

## RÉSUMÉ

*Influence de la densité de semis sur les populations de la mouche du sorgho,* Atherigona soccata *Rondani (Diptères: Muscidae)*

L'effet de densités croissantes de semis sur l'infestation du sorgho par *A. soccata* a été étudié dans la Province du Sud Nyanza, au Kenya. Les parcelles de densité minimale (22 plantes au $m^2$) reçurent 3,35 fois moins d'œufs que celles de densité maximale (704 plantes au $m^2$). En termes de nombre d'œufs par plante, la décroissance en fonction de la densité de semis suit une courbe d'équation $y = ax^b$; en termes de nombre d'œufs par unité de surface, ceci correspond à une croissance selon une équation de la forme $y = ax^{b+1}$ à faible densité et $y = a' + b'$ Log x à densité plus élevée. Ce type de relation peut être expliqué par la conjonction de l'effet répulsif d'une végétation trop abondante et de la perte d'attractivité de plantes croissant à densité excessive. Les conséquences sur la survie des larve du premier stade sont également examinées.

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*Accepted:* June 2, 1981