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# The phenology of *Bemisia tabaci* (Homoptera: Aleyrodidae) populations on cassava in southern Côte d'Ivoire

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## Abstract

Population phenologies of the whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), in young cassava crops in Côte d'Ivoire, West Africa, are described for three field seasons. Populations of all stages were consistently greatest 6–12 weeks after the crop was planted. The number of adults on plants as well as on attractive and non-attractive sticky traps displayed cycles of buildup and decline each year, the periodicity of these cycles corresponding to the generation time of *B. tabaci* under field conditions. Adult population declines were probably caused by emigration from the crop. Rainfall was negatively correlated with both nymph and adult populations, possibly due to reduced oviposition after rain. *B. tabaci* is the vector of African cassava mosaic geminiviruses (ACMV) and the observed *B. tabaci* population trends fit well with the pattern of ACMV buildup in the crop.

## Introduction

The whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), has become an increasingly important cosmopolitan pest, both directly and as a vector of plant viruses (Byrne *et al.*, 1990). One of these viruses, apparently specific to *B. tabaci*, is the African cassava mosaic geminivirus (ACMV) which is the most economically important insect-transmitted plant pathogen in sub-Saharan Africa (Geddes, 1990; Thresh *et al.*, 1994).

Cassava, *Manihot esculenta* (Euphorbiaceae), is the most important staple food of southern Côte d'Ivoire. It is traditionally grown in a patchwork of small plots, comprising a range of local cultivars many of which are susceptible to ACMV. Cassava from these plots is harvested only when needed and rarely before it is a year old. This, together with the lengthy rainy season and extended planting period, means that stands of cassava of differing age are always available to *B. tabaci* and virtually all show African cassava mosaic disease (ACMD) symptoms.

Ecological studies of *B. tabaci* on cassava have been undertaken in Nigeria (Mound, 1963; Leuschner, 1978), Kenya (Seif, 1981; Robertson, 1987), Togo (Dengel, 1981) and more recently in Côte d'Ivoire (Abisgold & Fishpool, 1990; Fishpool *et al.*, unpublished data). In addition, a recent taxonomic study identified a biotype of *B. tabaci* from Côte d'Ivoire which is largely restricted to cassava (Burban *et al.*, 1992).

Research on the ACMD pathosystem in southern Côte d'Ivoire began in 1981 (for a review see Fauquet & Fargette, 1990). This paper stems from that investigation and describes the phenology of *B. tabaci* populations in relation to cassava-crop growth, climatic factors and the spread of

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ACMD. Other aspects of the ecology of *B. tabaci* on cassava such as spatial distribution and flight behaviour are con-

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For the other count, two randomly selected plants per block plus their four nearest neighbours were chosen. Data were and new leaves produced were obtained by selecting one plant per block from the main trial.

The trial was also checked weekly for ACMD incidence. All newly infected plants were tagged and the date plus their location recorded.

Rainfall and temperature data were obtained from the ORSTOM field station's meteorological site, some 300 m distant.

### *Data analysis*

The adult and nymph field counts as well as the trap data were examined by time-series analysis using Statgraphics software (STSC, 1991). The adult data, comprising twice weekly counts at alternating three and four day intervals, were divided into two subsets at weekly intervals since such analyses require that data points be separated by constant intervals. Periodograms were generated and the lengths of the most 'powerful' cycles in the data calculated. Cross-correlation coefficients were also calculated to test for relationships between the adult and nymph data.

The relationships between the adult, nymph and yellow-trap data sets and various meteorological and plant growth parameters were examined by stepwise regression. The variables, tested as weekly means, were rainfall, maximum and minimum temperature, root weight and leaf production. For this analysis the corresponding data for all three trials were treated as continuous series, although the adult data

[illegible]

infected cuttings. After the initial high, the incidence of new ACMD infections declined in all three years, followed by second and third peaks at various intervals throughout the season. The highest incidence of ACMD occurred in 1989, although the adult *B. tabaci* population was only ca. 50% the size attained in the other two years.

For a given trial, the different methods of sampling for nymphs produced population curves similar in structure and size (figs 1B, 2B, 3B). There is also a similarity between trials in overall trend as well as with the phenology of the corresponding adult populations. Thus, the pattern recurs of build up to one or more peaks from initial low levels, followed by a crash 90–100 DAP. The nymph data, however, generally lack the abrupt fluctuations between counts seen in the adult data probably because of the sessile nature of nymphs. In agreement with the adult data, the 1989 nymph numbers are much lower than those of 1988 and 1990.

Egg population data for the 1989 trial are shown, together with rainfall, in figure 2C. There is an initial peak in egg numbers around 50 DAP, immediately following the first peak in adult numbers (fig. 2A). Thereafter, there is a rapid decline such that by 70 DAP the number of eggs is only about 10% that of three weeks earlier and it then remains at approximately this level. The phenology of the 1990 data (fig. 3C) differs in that egg numbers peak at 73 DAP and then fluctuate over the remainder of the trial around a level attained ca. 40 DAP.

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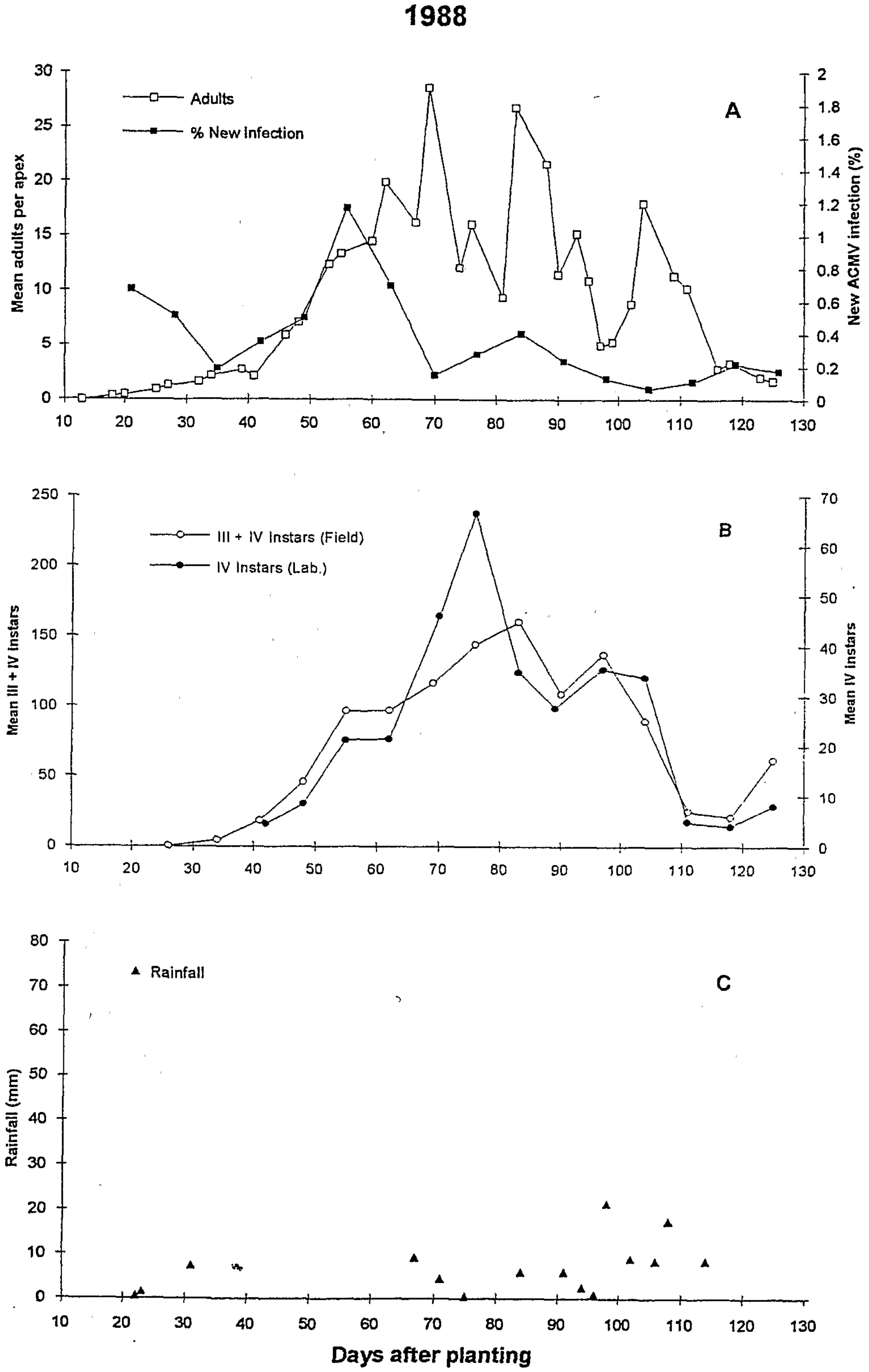

Fig. 1. 1988 data for; A) field counts of adult *Bemisia tabaci* expressed as mean numbers of adults

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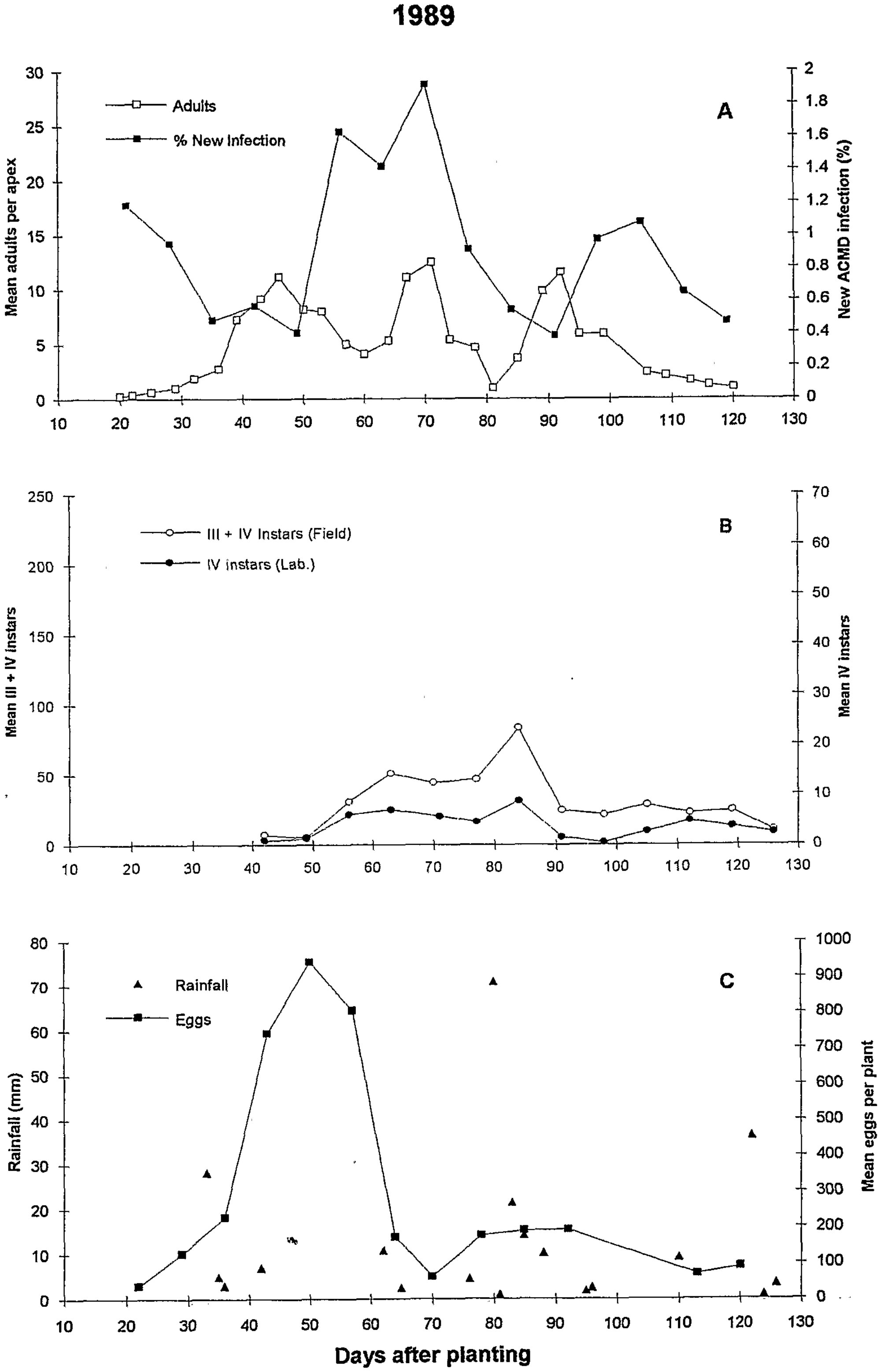

Fig. 2. 1989 data for: A) as for figure 1A except that there were ca. 1.77 apices per plant; B) as for figure 1B; C) rainfall plus mean numbers of eggs per cassava plant.

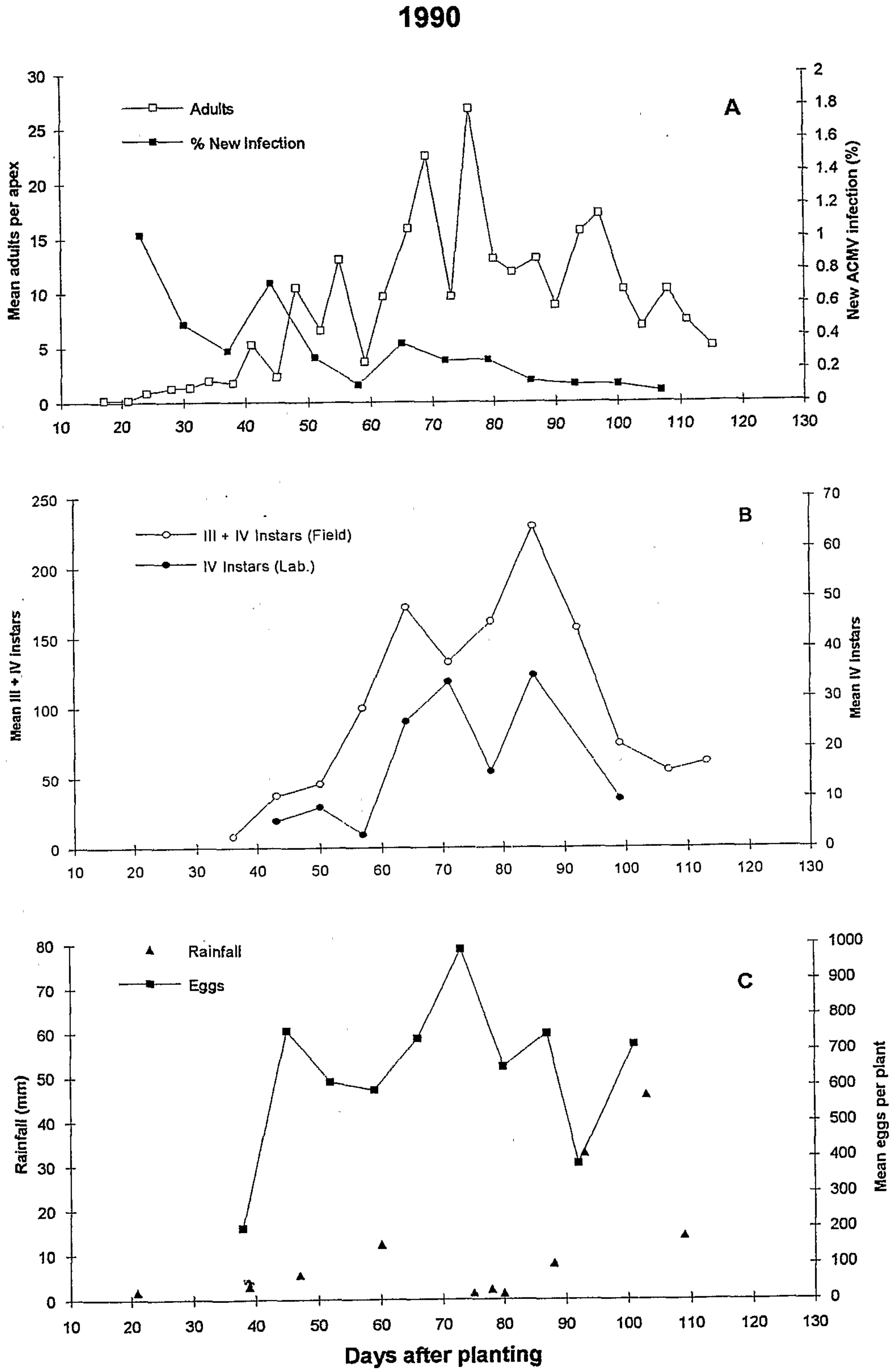

Fig. 3. 1990 data for: A) as for figure 1A except that there were ca. 1.75 apices per plant; B) as for figure 1B; C) as for figure 1C.

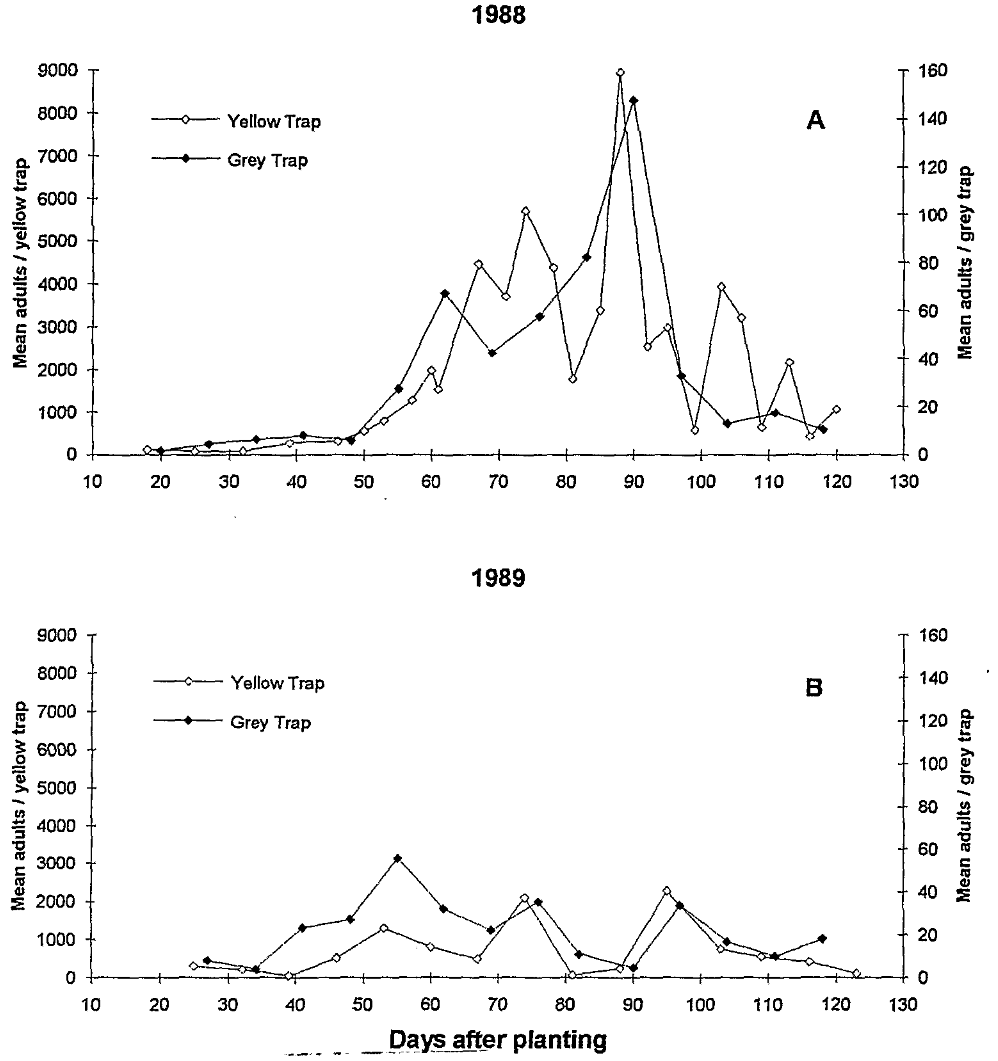

Fig. 4. Attractive (yellow) and unattractive (grey) trap catches of adult *Bemisia tabaci* for: A) 1988; B) 1989.

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Table 2. Cycle length (C.L.) in days, obtained from time-series analysis of adult and nymph data. Twice-weekly adult counts were divided into two series at weekly intervals for analysis. Fourth instars include 'pupae'.

| | 1988<br>C.L. (days) | 1989<br>C.L. (days) | 1990<br>C.L. (days) |
|---|---|---|---|
| Adults (series 1) | 17–19 | 20–22 | none |
| (series 2) | 17–19 | 22–24 | 21–28 |
| Nymphs (III+IV) (field counts) | 25 | 26, 20 | 23 |
| Nymphs (IV) (lab. counts) | 28 | 28 | 21 |

suppressed following rainfall both in the week immediately preceding the catch and, to a lesser degree, by rain 22–28 days before. The effects of minimum temperature are less consistent, having a significant effect only in three of the six data sets and with different time lags for the two adult field count series.

## Discussion

Whitefly identification currently relies almost entirely on nymph morphology and thus adult determination is inferred by association. Consequently, all adults counted in the field and on traps in this study were assumed to be [illegible]

Table 4. Significant correlations found by stepwise regression between meteorological variables and *Bemisia tabaci* data sets. All correlations negative. Time lags: t-3=3–4 weeks (22–28 days), t-1=1–2 weeks (8–14 days), t=1–7 days. Data sets for all three years have been treated as continuous series.

| | Parameter | Time lag | F Value | d.f. |
|---|---|---|---|---|
| Nymphs | | | | |
| Field | Rainfall | t-1 | 10.79** | 29 |
| Lab. (IV) | Rainfall | t-1 | 7.36* | 20 |
| Lab. (all) | Rainfall | t-1 | 7.43* | 22 |
| | Min. Temp. | t-1 | 5.82* | 22 |
| Adults | | | | |
| Data set 1 | Min. temp. | t-3 | 7.73** | 36 |
| | Rainfall | t-3 | 4.85* | 36 |
| Data set 2 | Min. Temp. | t-2 | 4.95* | 36 |
| | Rainfall | t-3 | 4.11* | 36 |
| Yellow Trap | Rainfall | t | 22.21** | 35 |
| | Rainfall | t-3 | 4.12* | 35 |

$^*P < 0.05$; $^{**}P < 0.01$.

obtained for an adult population in coastal Togo on a crop planted in April (Dengel, 1981) and in Nigeria, for a crop of unspecified planting date, using yellow sticky traps (Leuschner, 1978).

The three major fluctuations in adult population counts [illegible] decline in the adult field populations (figs 1A, 2A & 4) is consistent with this hypothesis.

Dispersal of *B. tabaci* populations has also been observed from cotton, where it is linked to decreasing food quality caused by host-plant ageing (Gerling & Horowitz, 1984; Berlinger, 1986; Cock, 1986; van Lenteren & Noldus, 1990). In cassava, tuberization begins 30–60 DAP (IITA, 1990) and the resultant changes in resource partitioning within the plant may adversely affect the nutritional quality of the aerial parts. Root weight, however, was not selected by stepwise regression as a determinant of adult or nymph population size (data not shown).

*Bemisia tabaci* populations are also influenced by climatic factors (Horowitz, 1986), although there is little consensus as to what these factors are or how they operate. Rainfall for instance, has been reported as reducing populations both on cassava (Golding, 1936; Mound, 1960; Dengel, 1981; Robertson, 1988) and cotton (Khalifa & El-Khider, 1964; Gameel, 1970). Both Leuschner (1978) and Lal (1981), however, reported no effect of rainfall, while Seif (1981) thought its effects were indirect but positive.

The time intervals over which rainfall was associated with reductions in the size of *B. tabaci* populations can be interpreted in terms of the length of the insect's life cycle (table 1). With a developmental time from egg to adult of 3 weeks, the reduction in adult field counts following rainfall 22–28 days earlier (table 4) suggests that rain may act to suppress oviposition and/or increase the mortality of first instar larvae which are mobile. The reduction in the nymph populations 8–14 days after rain is also consistent with this. No significant correlation was found between rain and adult counts 1–7 days later, suggesting that rainfall has no direct

In an associated study of the causes of variation in rates of ACMD spread at Adiopodoumé, it was found that disease increment in the second month after planting was highly significantly ($P < 0.001$) and dependent both upon average maximum temperature as well as mean adult *B. tabaci* population size in the preceding month (Fargette *et al.*, 1994). Rainfall during the same period, although significant at the 5% level, was much less important. It is surprising, therefore, that maximum temperature was not found to be a significant determinant of *B. tabaci* population size in this study. Meteorological data used here, however, were weekly means, whereas Fargette *et al.* (1994) used monthly averages to allow time for disease symptom expression. In addition, their study continued over several years while this analysis is confined to the same four months of each year. It is also possible that the relative importance of the different meteorological parameters varies seasonally.

Yellow traps have been used extensively to monitor *B. tabaci* populations in cotton (Gerling & Horowitz, 1984; Butler *et al.*, 1985; Byrne *et al.*, 1986) and, to a lesser extent, in cassava (Leuschner, 1978; Fargette *et al.*, 1985; Fishpool *et al.*, 1988; Robertson, 1987, 1988). Although others have considered them unsuccessful, e.g. Seif (1981), they proved effective in this study. The overall correspondence in the trends of the yellow- and grey-trap catches (fig. 4A, B) indicates that, although the attractiveness of the yellow trap may modify the behaviour of the adult whitefly, the effects on this analysis of any such changes seem to be solely quantitative.

The fluctuations in the numbers of plants newly showing symptoms of ACMD infection (figs 1A, 2A & 3A) fit well with what is known of the epidemiology of the disease

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