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The spatio-temporal distribution of *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera, Thripidae) life stages on cowpea, and development of sampling plans.

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Various sampling techniques were used to study the distribution of the different life stages of *Megalurothrips sjostedti* (TRYBOM) on cowpea plants: emergence cages for eggs, heat extraction for larvae and adults, and drop board and D-Vac for adults. The within-plant distribution was described by a preference index, whereas the between-plant distribution was analyzed using TAYLOR's Power Law. Enumerative sampling plans for adults were constructed for both the drop board and the D-Vac methods. The analysis of the temporal distribution over three years at four different locations in Benin showed a low population level during the first planting season, followed by a rapid build-up during the second season. The infestation levels depended on the number of thrips present on different host plants in a certain area and ready to colonize cowpea fields. The varieties studied showed different levels of resistance to *M. sjostedti*, presumably based on antixenosis.

Keywords: *Megalurothrips sjostedti*, thrips, cowpea, distribution, sampling.

INTRODUCTION

The bean flower thrips *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera, Thripidae) is one of the key pests on cowpea (AGYEN-SAMPONG, 1978; SINGH & TAYLOR, 1978; EZUEH, 1981; SINGH *et al.*, 1990; TAMÒ *et al.*, 1992b) causing the shedding of flower buds and flowers. *M. sjostedti* individuals select particular plant organs for oviposition and for nutritional purposes. The choice of these organs controls by large the way the thrips are interfering with the yield formation of the crop and is thus important for the assessment of the damage. The literature contains qualitative information on the preferred sites which permits the definition of the organs to be considered in any study of *M. sjostedti*-cowpea interactions (RÖSINGH, 1980; SALIFU, 1986). It does not provide quantitative information, however, particularly not with respect to the variety "Kpodjiguégué" considered in a comprehensive analysis of the cowpea agro-ecosystem (TAMÒ & BAUMGÄRTNER, 1992; TAMÒ *et al.*, 1992a). This is a serious gap for the understanding of such interactions, which will be filled in the first part of this paper dealing with the within-plant distribution of *M. sjostedti* life stages.

Appropriate sampling methods are a prerequisite for a study on the population dynamics. This is done in the second part of this paper which deals with the population trends as observed in different planting seasons and representative production areas in Benin.

MATERIAL AND METHODS

The study is restricted to plant-inhabiting life stages (eggs, larvae, and adults), and no attempt is made to investigate the distribution of prepupae and pupae living in the soil.

Sampling techniques

Eggs (within-plant distribution)

The within-plant distribution was studied as follows. Like other Terebrantia, *M. sjostedti* uses an ovipositor to lay the eggs into the plant tissue. For this reason, they can not be directly observed but made visible by dissolving the chlorophyll of the plant tissue (LEWIS, 1973; SOUTHWOOD, 1978). Unfortunately, this method kills them, and precludes therefore any study of embryonic development. The presence of viable eggs could only be determined indirectly by counting the hatching 1st instar larvae collected in emergence cages, consisting of a bottomless PVC cylinder (11 cm length, 6.5 cm diameter) with a tightly closing cover. The cylinder was placed upside-down, and a PVC funnel (8 cm length, 6.5 cm diameter) was glued onto it. The negative geotactic behavior of the newly hatched larvae (LEWIS, 1973) induced them to crawl along the funnel into a transparent collecting tube (3.2 cm length, 1.2 cm diameter) placed on top of it. The tubes were examined one week after installation, and the larvae counted under a binocular microscope.

In a first experiment, the spatial distribution was investigated for the different plant organs known to be preferred for oviposition (RÖSINGH, 1980; SALIFU, 1986). The samples were taken from a field planted at the IITA Biological Control Center for Africa in Abomey-Calavi (further called 'the Center') on September 13th, 1988, with the local variety 'Gbotogbongwe' (0.04 ha, spacing 0.25 x 0.75 m). Twice a week, leaf petioles (organ 1) and whole inflorescences (organ 2) comprising the peduncle, the inflorescence axis ('the cushion', see OJEHOMON, 1968a, b) and the flower buds were collected on 3 different locations of each plant in a set of 20 randomly chosen plants. For each of the two plant organs, one sample was taken at each the 8th and 12th mainstem node, and the 2nd node of the 3rd branch. These nodes are chosen because they appear at different times, allowing to assess changes of preference through time.

A second experiment considered the spatial distribution of *M. sjostedti* eggs on growing inflorescences only. For this purpose, samples were taken on a 0.3 ha cowpea field planted at the Center on May 7th, 1990, with the local variety 'Kpodjiguégué' (spacing 0.25 x 0.75 m). On 10 randomly selected plants, one inflorescence for each phenological class (described in Tab. 1) per plant was collected in biweekly intervals. Each class was separated into peduncles and cushions (organ 1), reproductive structures such as flower buds and flowers (organ 2), and pods (organ 3), when present. The plant organs were put separately into the emergence cages, and the hatching larvae were counted with the same methodology described above.

Larvae (within-plant distribution)

The within-plant study considered the two first larval instars (customarily called larvae, see LEWIS, 1973). The data were collected from two fields planted at the Center on May 7th (0.3 ha), and on September 13th, 1990 (0.24 ha), both with

Tab. 1. Phenological stages of the cowpea inflorescence used to define classes (I-V) for the assessment of the oviposition preference of *Megalurothrips sjostedti*.

class	definition
I	4-6 visible flower buds, the two biggest buds still enclosed in stipules
II	>8 visible buds, the two biggest buds in the bud-break phase (green petals visible)
III	the oldest pod on the inflorescence 5-10 cm long
IV	the oldest pod on the inflorescence 10-15 cm long
V	the oldest pod on the inflorescence >15 cm long

the local variety 'Kpodjiguégué' (spacing 0.25 x 0.75 m). The sample units belonged to four different plant organs: terminal vegetative buds (organ 1), young inflorescences with visible flower buds (organ 2), inflorescences with swelling flower buds (organ 3), and inflorescences with one open flower (organ 4). One organ per plant was collected biweekly on 10 randomly selected plants. The organs were clipped with a pair of scissors into a cylindrical collecting box, each constructed of a ring of transparent polyacryl (3.5 cm length, 6 cm diameter) closed with two tightly fitting caps. The samples were then brought to the laboratory, where the thrips larvae were extracted from the plant organs as follows. A wire tray, holding the collecting boxes, was put into a small drying oven directly on the bottom plate, i.e. where heat is generated. The oven was turned on for 3 minutes only, so that the air temperature inside did not exceed 35 °C, but continued to increase for several minutes after the oven was switched off. The bottom of the collecting boxes became hot because of heat conduction through the wire tray. This way the heat was transmitted to the plant organ laying on the bottom of each box. As the temperature increased, the thrips larvae on the organ escaped to the cooler areas of the collecting box, where they could be easily recovered. The temperature killed the thrips larvae in approximately 5 min. Under a binocular microscope, the 1st and 2nd instar larvae on the inner surface of the collecting box were counted. To assess the efficiency of the method, the plant organ of each box was dissected under the binocular microscope, and the thrips remaining in the organ were counted.

Adults (within- and between-plant distribution)

Three different methods were used to study the within and between-plant distribution of adults: the drop board and the D-Vac were used for the latter, and the heat extraction method for the first purpose.

The *drop board* was used to sample fields planted at the Center in 1987, 1988, and 1989 with different varieties. The details about planting dates, varieties used, and sample size are given in Tab. 2. This method was chosen because it was the only known field sampling technique suitable for these purposes (Salifu & Singh, 1987). In order to avoid the use of large quantities of polyethylene sheets and Tangle Foot®, the method has been slightly modified.

Plywood boards (surface 40 x 40 cm, thickness 0.6 cm) were covered on one side with a white sheet of paper having a surface subdivided into a grid of 16 squares

Tab. 2. Planting date, variety used, and sample size for fields sampled with the drop board method during 1987-90 at the Center in Abomey-Calavi.

planting date	variety	sample size
23/09/87 (2nd season)	IT-84E-2246	20
23/09/87 (2nd season)	Kpodjiguégué (local)	20
22/03/88 (1st season)	Kpodjiguégué (local)	20
13/09/88 (2nd season)	IT-84E-2246	20
13/09/88 (2nd season)	Kpodjiguégué (local)	20
14/09/89 (2nd season)	Kpodjiguégué (local)	20
07/05/90 (1st season)	Kpodjiguégué (local)	20

of 100 cm^2 each to facilitate counting. The whole board was sealed in a solid transparent polyethylene sheet. With a large brush, a thin film of engine oil (10 W 30) was uniformly applied on the side of the board covered by the paper. In the field, the board was placed under the canopy of a randomly selected plant which was subsequently shaken 5 times. All adult individuals of *M. sjostedti* trapped in the oil film were immediately counted *in situ*. Afterwards, the counting surface was cleaned so that it could be used for the next sample.

The *D-Vac aspirator* (SOUTHWOOD, 1978) used for this study was not a commercially available model, but assembled from different parts as follows. The suction device consisted of a knapsack sprayer, powered by a two-stroke engine. A metallic cap with a lateral pipe (8 cm diameter, 20 cm length) was welded on the air inflow opening (32 cm diameter). A flexible vacuum-cleaner hose (6 cm diameter, 3 m length) was attached to the lateral inflow pipe. The aspirator nozzle consisted of a bottomless PVC flower pot (16 cm diameter), glued on the distal end of the hose. The insects were collected in aspiration bags, made of fine mesh screen (100 μm), and tied up with a drawstring, these being inserted into the pot. To avoid the collection of large insects and plant parts, a tightly-fitting cover of galvanized iron screen (mesh size 0.8 cm) was placed on the nozzle.

The sampling procedure in the field consisted of five different steps: 1) during the first 5-10 seconds, the exterior layer of the plant canopy was sampled; 2) with quick shaking movements, the aspirating nozzle was subsequently inserted into the interior of the plant and directed to the reproductive structures which bear the larger part of the thrips population; 3) the aspiration bag containing the insect sample was quickly closed and tied up with a string, and put into a killing jar containing ethyl acetate; 4) after 3-4 minutes, the aspiration bag was removed, and put into a precoded paper bag; 5) a new aspiration bag was inserted into the pot and another plant was randomly selected for sampling.

The bags were subsequently brought to the laboratory, the contents carefully brushed into glass petri dishes (9 cm diameter), and *M. sjostedti* adults counted under the binocular microscope. Other insects of interest were also counted and prepared for identification.

The locations of the fields, as well as the planting dates, the varieties used and the sample size are given in Tab. 3. At the Center, fields were sampled biweekly, whereas farmers fields could be sampled once a week only.

Tab. 3. Location, planting date, variety used, and sample size for fields sampled with the D-Vac method during 1988-90 in Benin. The asterisk (*) indicates fields that were used for the assessment of the temporal dynamics of *Megalurothrips sjostedti*.

location	planting date	variety	sample size
Center	13/09/88 (2nd season)	IT-84E-2246	20*
Center	13/09/88 (2nd season)	Kpodjiguégué (local)	20*
Center	11/05/89 (1st season)	TVx3236	20*
Center	11/05/89 (1st season)	IT-82E-32	20*
Center	11/05/89 (1st season)	Kpodjiguégué (local)	20*
Center	11/05/89 (1st season)	Gbotogbongwe (local)	20*
Center	14/09/89 (2nd season)	TVx3236	20*
Center	14/09/89 (2nd season)	IT-82E-32	20*
Center	14/09/89 (2nd season)	Kpodjiguégué (local)	20*
Center	14/09/89 (2nd season)	Gbotogbongwe (local)	20*
Center	07/05/90 (1st season)	Kpodjiguégué (local)	20*
Center	13/09/90 (2nd season)	Kpodjiguégué (local)	20*
Zouzouvou (Mono)	02/09/88 (2nd season)	Kpodjiguégué (local)	5
Zouzouvou (Mono)	03/09/88 (2nd season)	Kpodjiguégué (local)	5
Zouzouvou (Mono)	06/09/88 (2nd season)	Kpodjiguégué (local)	5
Zouzouvou (Mono)	02/09/88 (2nd season)	IT-84E-2246	5
Zouzouvou (Mono)	03/09/88 (2nd season)	IT-84E-2246	5
Zouzouvou (Mono)	06/09/88 (2nd season)	IT-84E-2246	5
Zouzouvou (Mono)	02/06/89 (1st season)	Gbotogbongwe (local)	10*
Zouzouvou (Mono)	03/06/89 (1st season)	Gbotogbongwe (local)	10*
Zouzouvou (Mono)	05/06/89 (1st season)	Gbotogbongwe (local)	10*
Zouzouvou (Mono)	03/06/89 (1st season)	IT-82E-32	10*
Zouzouvou (Mono)	03/06/89 (1st season)	IT-82E-32	10*
Zouzouvou (Mono)	05/06/89 (1st season)	IT-82E-32	10*
Toulehoudji (Mono)	11/09/88 (2nd season)	Kpodjiguégué (local)	5
Toulehoudji (Mono)	12/09/88 (2nd season)	Kpodjiguégué (local)	5
Toulehoudji (Mono)	16/09/88 (2nd season)	Kpodjiguégué (local)	5
Toulehoudji (Mono)	11/09/88 (2nd season)	IT-84E-2246	5
Toulehoudji (Mono)	12/09/88 (2nd season)	IT-84E-2246	5
Toulehoudji (Mono)	16/09/88 (2nd season)	IT-84E-2246	5
Tchi Ahomadegbe (Mono)	07/06/89 (1st season)	Gbotogbongwe (local)	10*
Tchi Ahomadegbe (Mono)	09/06/89 (1st season)	Gbotogbongwe (local)	10*
Tchi Ahomadegbe (Mono)	12/06/89 (1st season)	Gbotogbongwe (local)	10*
Tchi Ahomadegbe (Mono)	07/06/89 (1st season)	IT-82E-32	10*
Tchi Ahomadegbe (Mono)	09/06/89 (1st season)	IT-82E-32	10*
Tchi Ahomadegbe (Mono)	12/06/89 (1st season)	IT-82E-32	10*
Sohedji (Zou)	04/06/89 (1st season)	TVx3236	20*
Sohedji (Zou)	04/06/89 (1st season)	IT-82E-32	20*
Sohedji (Zou)	04/06/89 (1st season)	Kpodjiguégué (local)	20*
Sohedji (Zou)	04/06/89 (1st season)	Gbotogbongwe (local)	20*
Tannouwo (Zou)	27/07/89 (2nd season)	IT-82E-32	10
Tannouwo (Zou)	05/08/89 (2nd season)	IT-82E-32	10
Tannouwo (Zou)	07/08/89 (2nd season)	IT-82E-32	10
Tannouwo (Zou)	01/09/89 (2nd season)	Kododabo (local)	10
Tannouwo (Zou)	10/09/89 (2nd season)	Sewe (local)	10
Tannouwo (Zou)	10/09/89 (2nd season)	Sewe (local)	10
Tannouwo (Zou)	10/09/89 (2nd season)	Gbotogbongwe (local)	10
Tannouwo (Zou)	27/09/89 (2nd season)	IT-82E-32	10
Djoho (Zou)	26/08/89 (2nd season)	Gbotogbongwe (local)	10
Djoho (Zou)	26/08/89 (2nd season)	IT-82E-32	10
Goho (Zou)	26/08/89 (2nd season)	IT-82E-32	10
Goho (Zou)	26/08/89 (2nd season)	Sewe (local)	10

For both the drop board and the D-Vac method, the sampling unit was represented by one plant.

The within-plant distribution of *M. sjostedti* adults could be gathered with the *heat extraction method* described above, by examining the same samples used for the larvae.

Analysis of the spatial distribution and construction of sampling plans

The within-plant distribution of eggs, larvae and adults

The distribution of the *M. sjostedti* life stages (eggs, larvae, adults) on the different plant organs depends on their attractiveness both as oviposition and feeding sites. Hence, the within-plant distribution can be expressed by the measure of preference w, derived from a probability function presented in CHESSON (1978, 1983)

$$P_i = \frac{w_i \cdot n_i}{\sum_{i=1}^{m} (w_i \cdot n_i)} \qquad [1]$$

where P_i represents the probability that a particular life stage is encountered on the plant organ of type $i = 1, 2, ..., m$; n_i is the number of the organs of type i present, and $w_i \in [0,1]$ is the preference index, estimated by $\hat{w}_i$ via a maximum likelihood technique applied to the subsequent eqn. [2]. The presentation of the assumptions of the function and the mathematical framework underlying this estimation goes beyond the scope of this study, and the interested reader is referred to CHESSON (1978).

During the observation periods it was assumed that the selection of neither the oviposition nor the feeding sites had an influence on n_i. The preference could thus be computed for each phenological class by the following equation

$$\hat{w}_i = \frac{r_i / n_i}{\sum_{i=1}^{m} (r_i / n_i)} \qquad \text{for } i = 1, 2, ..., m \qquad [2]$$

where r_i is the number of *M. sjostedti* individuals observed on the organ of type i. For the estimation of the preference index $\hat{w}_i$, CHESSON (1983) suggests the expression of both n_i and r_i as a percentage of the total.

The between-plant distribution of adults

The relationship between the estimated mean m and variance s^2 of the sampled population has been expressed by TAYLOR (1961) with

$$s^2 = a \cdot m^b \qquad [3]$$

which is valid for a large number of species and constant through time (TAYLOR *et al.*, 1978). The sampling factor a and the aggregation index b can easily be

estimated from the linear regression between the $log_{10}s^2$ and the $log_{10}m$ (SOUTHWOOD, 1978).

RUESINK (1980) and WILSON & ROOM (1983) proposed the estimation of the optimum sample size n using the equations of KARANDINOS (1976)

$$n = a \left(\frac{z\, a/2}{d} \right)^2 m^{b-2} \qquad [4]$$

where the probability for the real population mean to be found in the interval $m \pm d$ is $P = 1-\alpha$, $z_{\alpha/2}$ being the upper $\alpha/2$ point of the standard normal distribution (for $\alpha = 0.05$, $z_{\alpha/2} = 1.96$), and the precision level d represents a fixed proportion of the observed population mean m. The enumerative sampling plan expresses the sample size n as a function of the mean density m, and is formulated for both the drop board and the D-Vac methods, in order to assess their efficiency.

Temporal dynamics

The seasonal trends in the abundance of adult females has been studied at different localities. From the fields specified in Tab. 3, only those were selected for the analysis which were sampled more than 5 consecutive times. Only the D-Vac method described above has been used for this purpose.

RESULTS AND DISCUSSION

Within-plant distribution

Eggs

The preference index is calculated for each organ class (Tab. 1). Hence, the analysis can be extended to the whole plant only indirectly, i.e. by presenting the preference through time. In Fig. 1, the oviposition patterns for a second season plant-

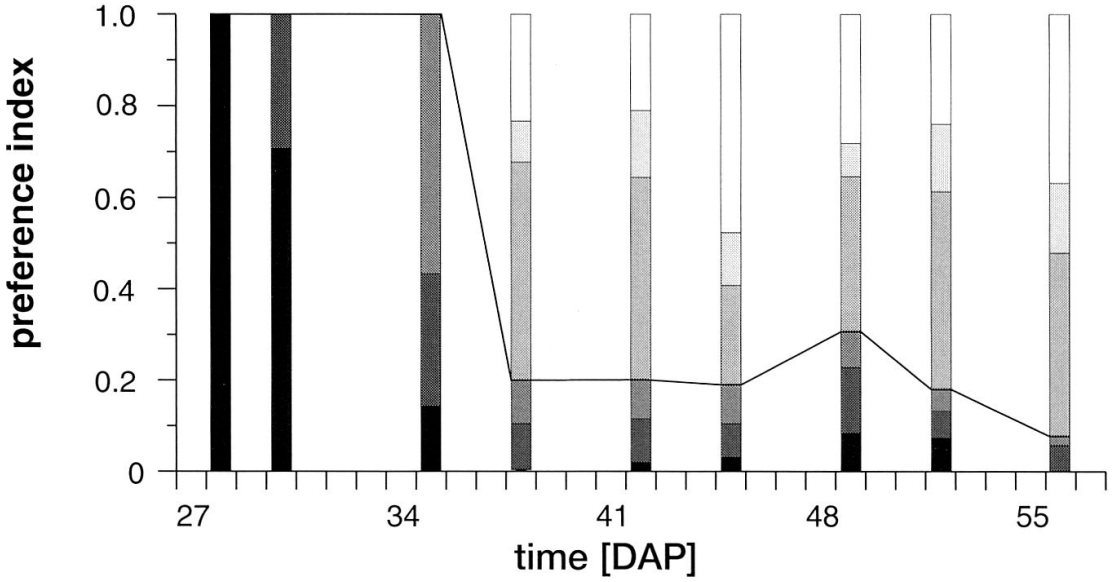

Fig. 1. Within-plant distribution of *Megalurothrips sjostedti* eggs, expressed as the measure of oviposition preference between leaf petioles and inflorescences on different position on the cowpea plant. [petioles: ■ = on the 8th mainstem node; ■ = on the 12th mainstem node; ■ = on the 2nd node of the 3rd branch; inflorescences: ▨ = on the 8th mainstem node; ▨ = on the 12th mainstem node; □ = on the 2nd node of the 3rd branch. The line shows the separation between petioles and inflorescences].

ing are represented as the measure of preference for the leaf petioles and inflorescences on different positions on the plant. During the first week of observation, i.e. for 27<DAP<36, the inflorescences were too small to exert any attraction on ovipositing females (DAP=day after planting). During the same period, the preference for the three different positioned leaf petioles was strongly related to their subsequent appearance on the plant, indicating a preference for younger ones. As soon as the peduncles started to elongate (DAP>35), the inflorescences were preferred as oviposition substrate by large, their compound $\hat{w}_i$ values fluctuating between 0.7 and 0.9. In contrast to the observations on the petioles, the inflorescences developing first were preferred for oviposition, i.e. in order of preference the 8th on the mainstem, the 3rd on the 2nd lateral shoot, and the 12th on the mainstem, irrespective of age. However, the proportion of preference among the different organs for DAP>35 seemed to be stable through time. This could be partially explained by the fact that, considering the high population level of *M. sjostedti* during the period under study, the last inflorescences might have suffered more feeding damage, so that they were no more attractive for oviposition than the older ones.

RÖSINGH (1980) found a higher oviposition preference for leaf petioles, compared to stipules, young inflorescences without flowers, and leaves. However, his data were obtained after having exposed potted plants in an infested field during 3 days, and represent consequently a snapshot only. Although there is no indication of the age of the potted plants used for his experiment, comparison with Fig. 1 gives 35 to 38 DAP as the most likely period of observation.

The evaluation of oviposition preference for the different parts of the inflorescence (the peduncle and the cushion, flower buds, and growing pods) is presented in Fig. 2. The subdivision of the inflorescences in phenological classes (Tab. 1)

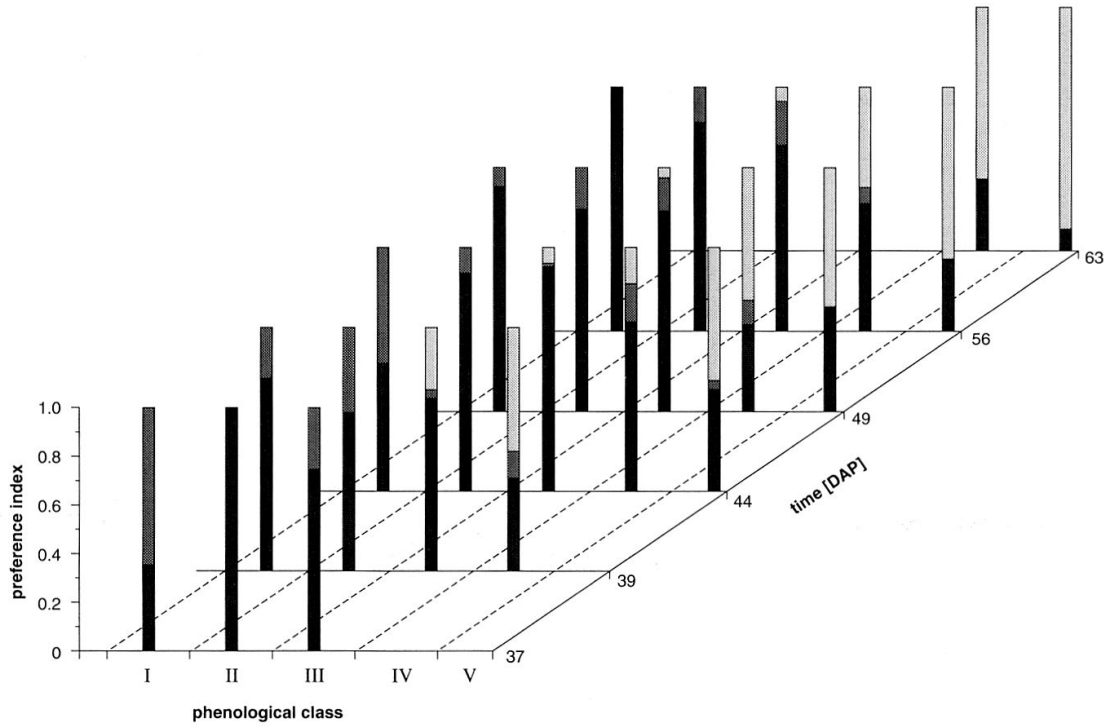

Fig. 2. Within-plant distribution of *Megalurothrips sjostedti* eggs, expressed as the measure of oviposition preference between different reproductive organs of the cowpea plant. The definition of the phenological classes I-V is given in Tab. 1. [■ = peduncles including the inflorescence axis; ■ = flower buds; ■ = growing pods].

allowed to investigate the influence of both age and phenology on the oviposition pattern.

The importance of flower buds as oviposition substrate was confined to the early flowering period (36<DAP<45) for young inflorescences only (class I and II). The oviposition choice for green pods was strongly related to their phenological stage: pods longer than 5 cm (class IV and V) were preferred, and their attractiveness increased steadily from DAP 49. However, the peduncles and the cushion accounted for most of the preference across classes and time. Similar results were presented in SALIFU (1986), although his analysis did not include a time frame, neither did it consider the pods as oviposition site.

It is noteworthy that *M. sjostedti* lays eggs into pods at the end of the plant growing cycle, in spite of the fact that the offspring will not find sufficient food to survive.

In conclusion, adult *M. sjostedti* have clear preferences for oviposition sites. Nevertheless, the cowpea plant permanently offers sites for oviposition.

Larvae and adults

1st season cowpea crop: The within-plant distribution of 1st and 2nd instar larvae, and adult females is depicted in Fig. 3A-C. No adult male was recorded in any of the samples. During the pre-flowering period, in this case from 29<DAP<38, older inflorescences with swelling flower buds were generally preferred by larvae and adults over terminal vegetative buds, and to younger inflorescences with visible flower buds, respectively. With the onset of flowering (DAP>37), inflorescences with open flowers were by far the most attractive plant organs among the ones considered. This clear preference for inflorescences bearing open flowers could be explained by the search for favorable microclimatic conditions. Moreover, adult females feed on pollen inside the flowers. The absence of adult males in cowpea flowers has already been observed by TAYLOR (1974), who hypothesized that males are poor fliers and disperse inefficiently.

No substantial difference seemed to exist between the within-plant distribution of 1st instar larvae (Fig. 3A) and 2nd instar larvae (Fig. 3B). Although the dispersal of 1st instar larvae has not been quantified yet, some observations on their mobility suggest that they are able to reach any organ within the plant which was attractive to them.

2nd season cowpea crop: The within-plant distribution patterns are presented in Fig. 4A-C. In general, during the pre-flowering period the terminal vegetative bud was preferred over older inflorescences with developing flower buds, and younger inflorescences. After DAP 39, the presence of open flowers on inflorescences was the strongest attracting factor, while the differences between the different life stages were less accentuated as for the 1st growing season.

In conclusion, the observations reflect the results summarized by LEWIS (1973), which suggest that thrips are, in general, attracted by thigmotactic stimuli to locations called escapes in this work.

The difference in the preference between the two planting seasons can be explained by comparing the abundance of *M. sjostedti* on the same fields considered by this study. During the 1st season in 1990, the thrips population density was rather low (Fig. 7C), whereas it was up to 4 times higher during the 2nd season (Fig. 7D). Thrips on inflorescences with macroscopic flower buds can find a very limited

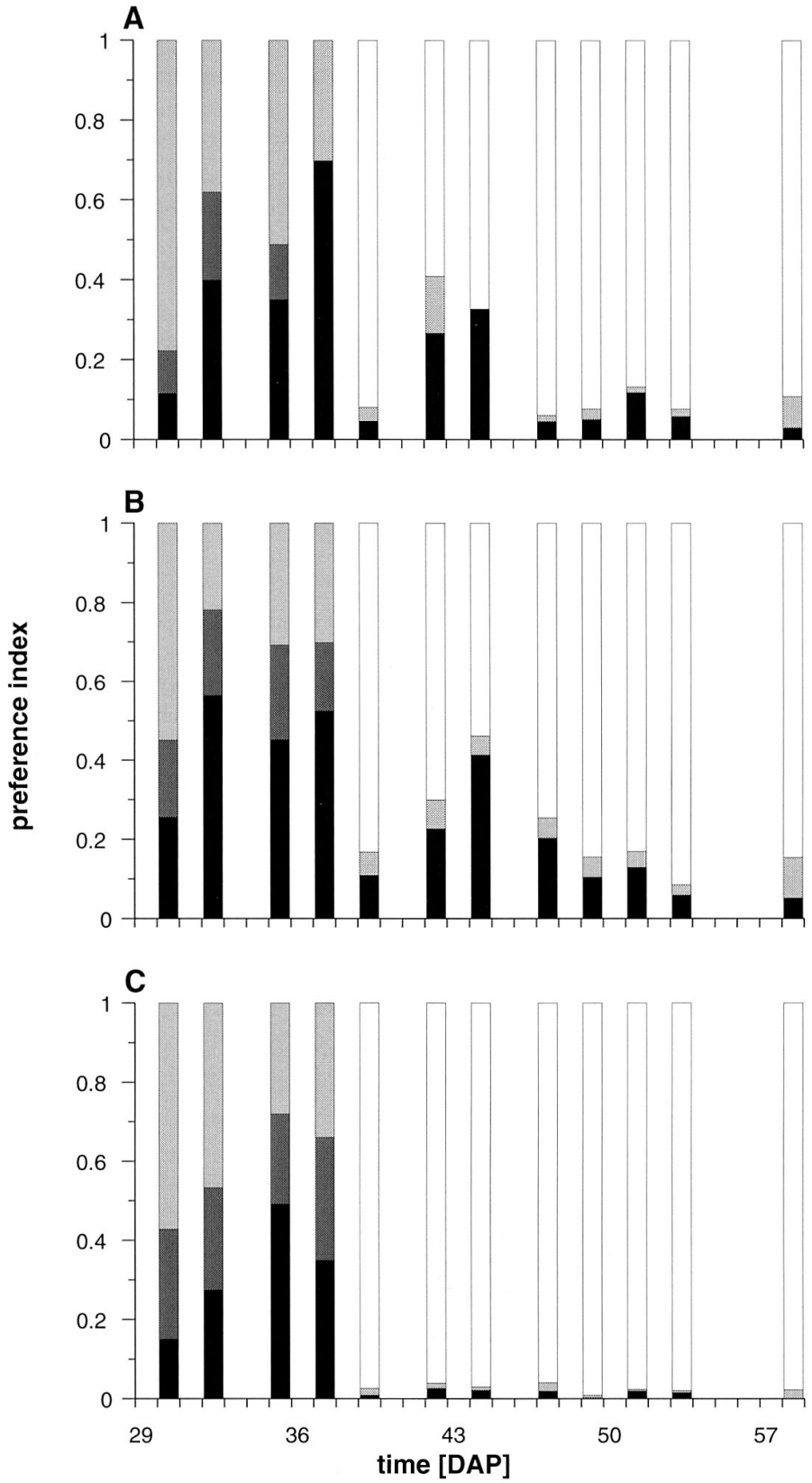

Fig. 3. Within-plant distribution of *Megalurothrips sjostedti* 1st (A) and 2nd (B) instar larvae, as well as adult females (C), expressed as the measure of preference between different plant organs for a first season cowpea planting. [■ = terminal vegetative buds; ▩ = young inflorescences with visible flower buds; ▨ = inflorescences with swelling flower buds; □ = inflorescences with one open flower].

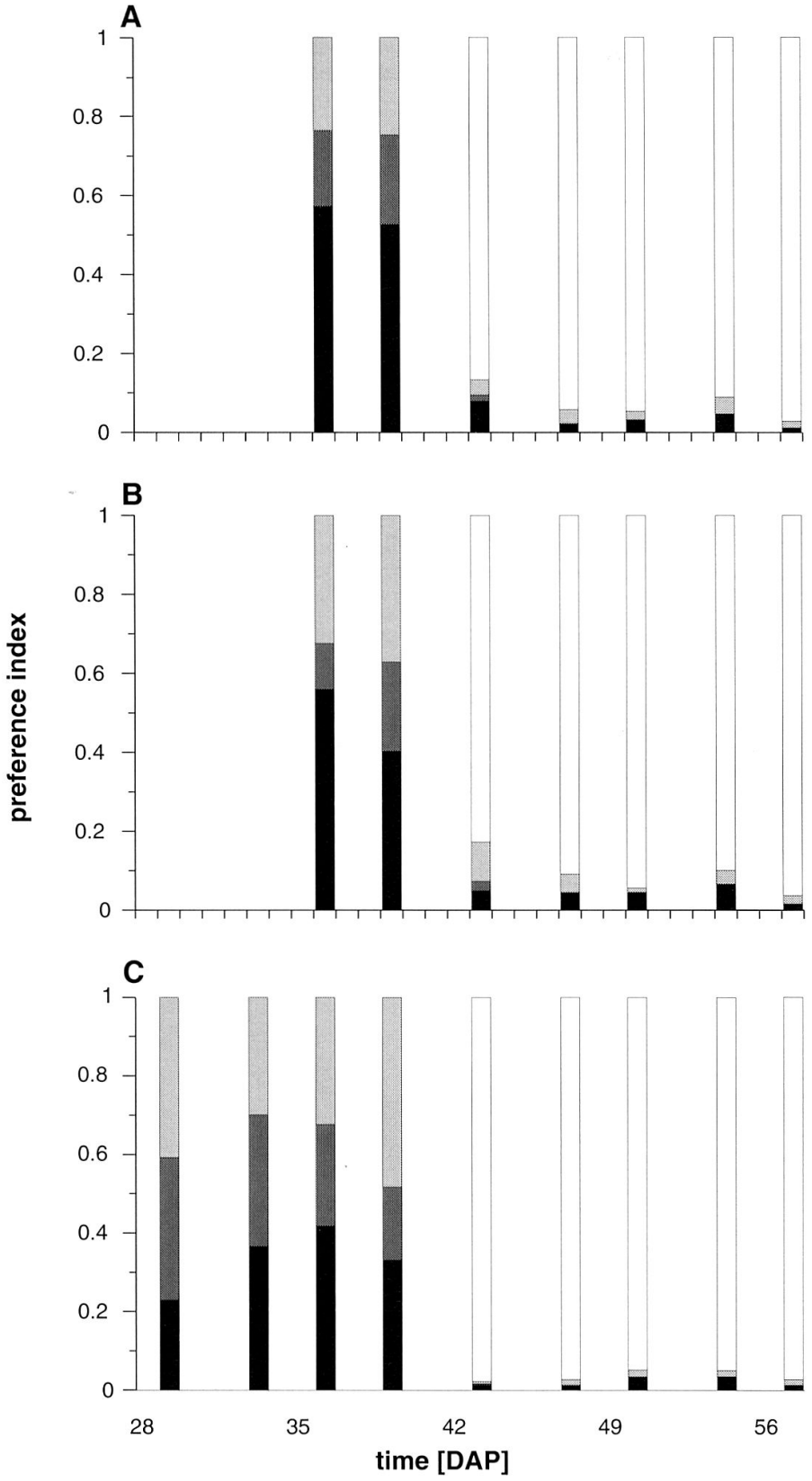

Fig. 4. Within-plant distribution of *Megalurothrips sjostedti* 1st (A) and 2nd (B) instar larvae, as well as adult females (C), expressed as the measure of preference between different plant organs for a second season cowpea planting. [■ = terminal vegetative buds; ▩ = young inflorescences with visible flower buds; ▨ = inflorescences with swelling flower buds; □ = inflorescences with one open flower].

number of escapes, mostly in the space between the bud and the cushion, or between two neighboring buds. In addition, these inflorescences are more subjected to feeding damage, resulting in shedding of buds, and, consequently, loss of escapes. This is a plausible reason why, by the higher thrips population pressure, inflorescences with growing flower buds seem to have a kind of carrying capacity for *M. sjostedti* life stages, whereas the preference for terminal vegetative buds and open flowers is proportional to the infestation level.

Not a single thrips was found inside the plant organs after the heat treatment, showing that this method is very accurate. However, unlike in alcohol samples (SALIFU & SINGH, 1987), the thrips need to be counted immediately after the heat treatment, in order to avoid their decay.

Between-plant distribution, and development of sampling plans

The between-plant distribution was assessed with pooled data sampled with either the drop board or the D-Vac method. The linear regression between the log_{10} of the estimated population mean and the log_{10} of the related variances is presented in Fig. 5 for both methods. The visual comparison of the regression lines indicates that the two methods are in close agreement. TAYLOR's coefficients are: $a = 1.5962$, $b = 1.6269$ for the drop-board method, and $a = 0.7633$, $b = 1.6271$ for the D-Vac method. These values suggest a moderate contagion, but their biological interpretation is still controversial (SOUTHWOOD, 1978). Nevertheless, the similarity between

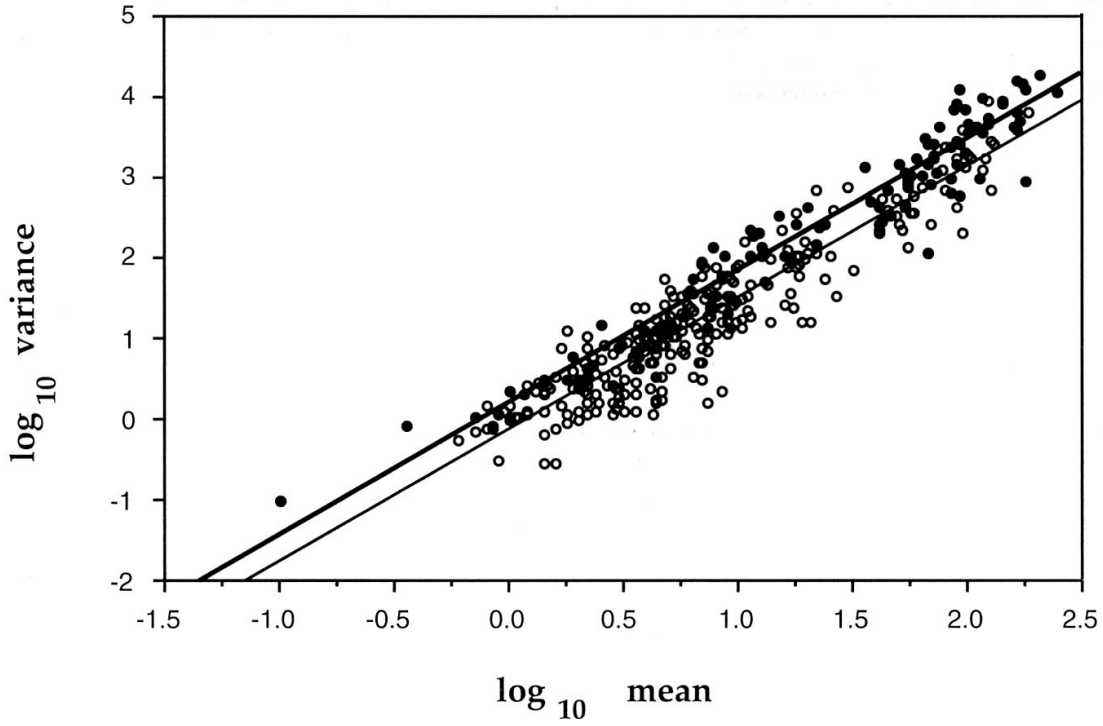

Fig. 5. Relationship between the $\log_{10}$ of the estimated population mean of *Megalurothrips sjostedti* and the $\log_{10}$ of the related variance for the drop board (●) and the D-Vac method (○), obtained with pooled data from cowpea fields planted according to Tab. 2 and 3, respectively. The linear regression line for the drop board method (▬) has an intercept of 0.2031, and a slope of 1.6269, with $R^2 = 0.937$. For the D-Vac method (——), the intercept is -0.1173, the slope 1.6271, and $R^2 = 0.870$.

the *b*'s supports TAYLOR *et al.*, (1978) hypothesis that the slope is independent of the method and characteristic for a species, while *a* is method-dependent.

The enumerative sampling plans for both methods are compared in Fig. 6. At the higher reliability level (proportion $d = 0.2$), the advantage of the D-Vac method in terms of sampling efficiency was more pronounced than for the lower reliability

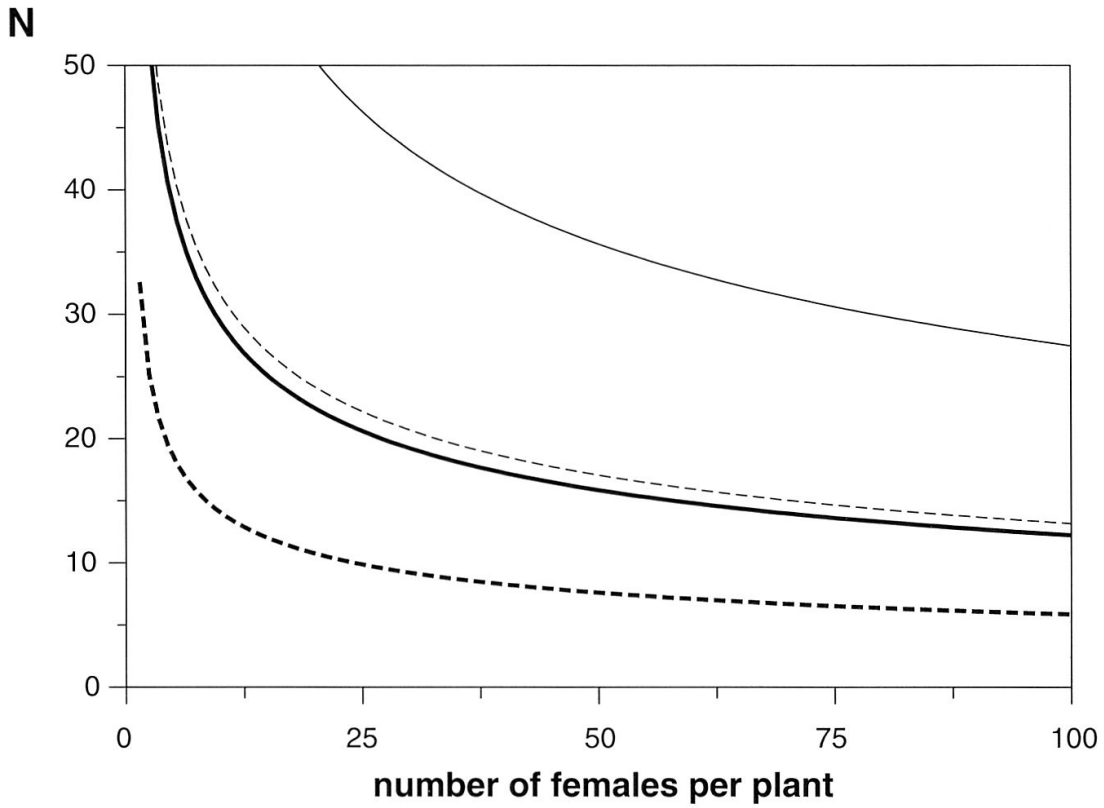

Fig. 6. Enumerative sampling plans for *Megalurothrips sjostedti* adult females comparing the drop board with the D-Vac method. [N: number of samples to be taken to estimate the population density with a reliability level given as a fixed proportion of the mean (m), and a probability of P = 0.95; drop board: reliability level of 0.2 (——) and 0.3 (- - - -); D-Vac: reliability level of 0.2 (▬▬) and 0.3 (▪▪▪▪)].

level (proportion $d = 0.3$). A defined proportion $d = 0.2$ has been widely used for enumerative sampling plans in similar research projects (VON ARX *et al.*, 1984; CERUTTI *et al.*, 1988; BIANCHI *et al.*, 1989; SCHULTHESS *et al.*, 1989). In this case, a sample size of 20 would meet the desired precision level at a density over 30 individuals. This density is practically never reached during the 1st cropping season, whereas it is largely exceeded during the 2nd season.

With 20 aspiration bags, the reliability level for the D-Vac method, expressed as the proportion *d*, is between 0.3 and 0.2 for 1st season samplings, and below 0.2 for 2nd season samplings. This level is higher than the one obtained with a sample size of 20 and the drop board method. In addition, the D-Vac method is less time consuming in the field, and allows the collection of other arthropods of interest for further studies. Consequently, it is preferred over the drop-board method.

Temporal dynamics

The seasonal trends of the adult females population are depicted in Fig. 7A-D for the Center in Abomey-Calavi, in Fig. 8A-C for the locality Tchi-Ahomadegbe in the Eastern Mono Department, in Fig. 9A-C for Zouzouvou on the Adja Plateau in the Western Mono Department, and in Fig. 10 for Sohedji in the Northern Zou Department. Adult males accounted for less than 0.01% of the catches, and were consequently not included in the analysis.

Center (Fig. 7A-D)

The population trend of *M. sjostedti* females was observed for both cropping seasons at the Center during two subsequent years. The visual comparison of the trends indicates that, generally, the differences between the seasons were by large more important than the differences between the years. In fact, the peak densities during the 2nd cropping season were from 4 to 20 times higher than during the 1st season, depending on the variety. During the 1st season in 1989, the average peak densities were low, ranging from about 4 females/plant on TVx3236, an improved IITA variety tolerant to moderate thrips infestation levels, to about 10 for the local variety 'Kpodjiguégué' (Fig. 7A). On the contrary, the infestation level during the 2nd season (Fig. 7B) was extremely high (average peak densities: about 71 for TVx3236 and 184 for 'Kpodjiguégué'), leading to the complete failure of all varieties.

Compared to 1989, the 1st season in 1990 was characterized by a higher population build-up (Fig. 7C), while the population level during the 2nd season was about half as much as in 1989 (Fig. 7D), allowing the formation of an acceptable grain yield (TAMÒ *et al.*, 1992a).

Tchi-Ahomadegbe (Fig. 8A-C)

Three fields with two varieties were sampled in this Southwestern Benin locality during the 1st cropping season (Tab. 3). The overall infestation level was low, not even reaching a mean of 10 adults per plant except on one occasion (Fig. 8A). The drop of the population of adult females observed in the late generative phase of the plant, around 62-66 DAP, could have been occasioned by the scarcity of suitable oviposition and food substrate (young inflorescences and open flowers), forcing them to leave the field. However, the cowpea varieties under study being of undetermined type, a second wave of flowering observed after DAP 66 could have attracted the adults back to the same field.

No major differences in thrips densities has been observed between the two varieties. The yields, however, appeared to be lower than for a standard variety. Hence, both appear to be rather susceptible to thrips damage.

Zouzouvou (Fig. 9A-C)

The trend of adult females densities in the other Southwestern Benin locality was similar to the one for Tchi-Ahomadegbe, though the peak densities were slightly higher. Since the varieties used in this locality were the same as in Tchi-Ahomadegbe, the same considerations regarding flowering periods and susceptibility were also valid in this case.

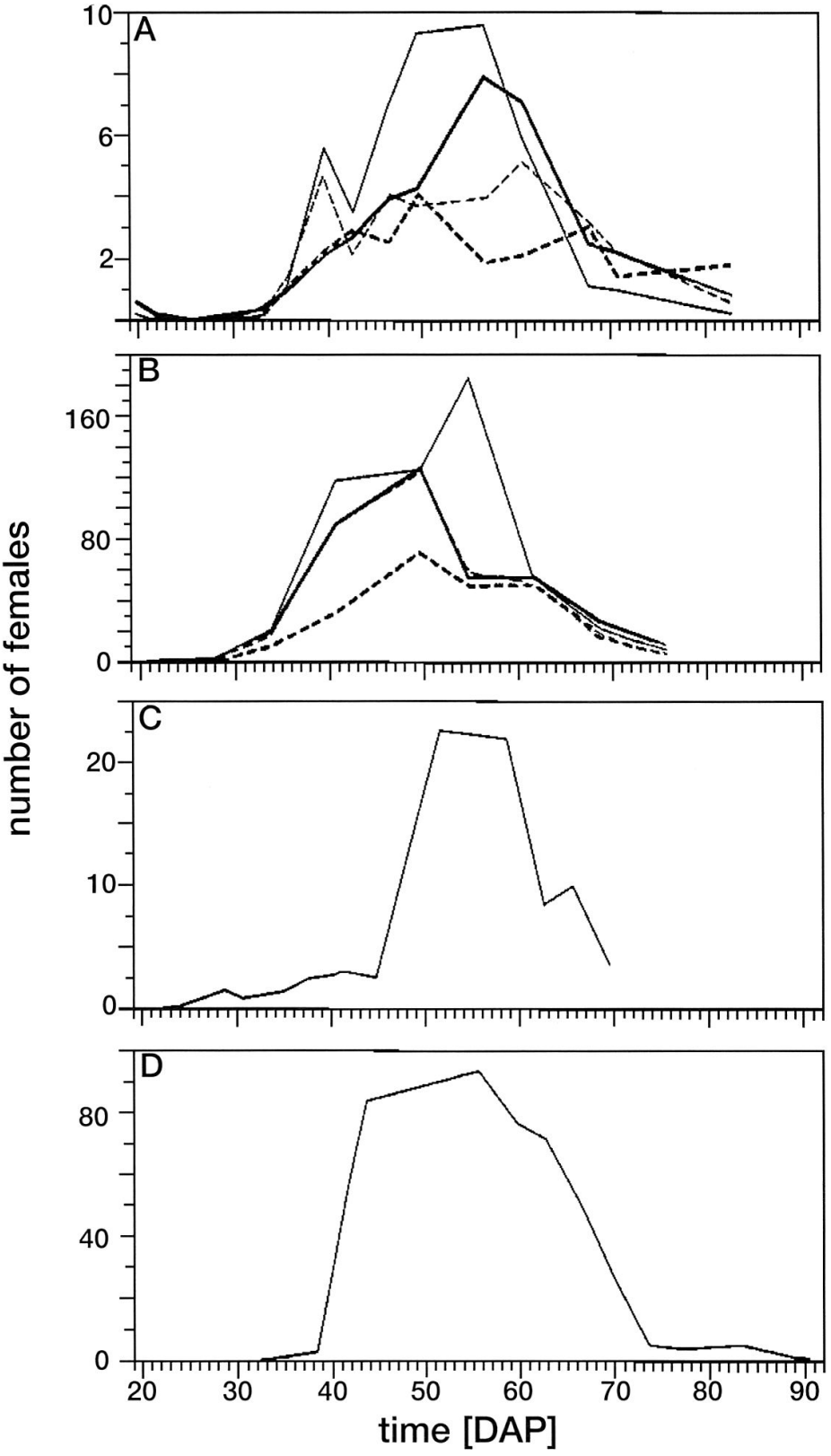

Fig. 7. Abundance pattern of *Megalurothrips sjostedti* adult females at the Center in Abomey-Calavi, for fields planted during the 1st (A) and the 2nd (B) cropping season in 1989 [cowpea varieties: Kpodjiguégué (——) Gbotogbongwe (- - - -) IT-82E-32 (▬▬) and TVx3236 (▪▪▪▪)], and during the 1st (C) and the 2nd (D) cropping season in 1990 with the variety Kpodjiguégué (——).

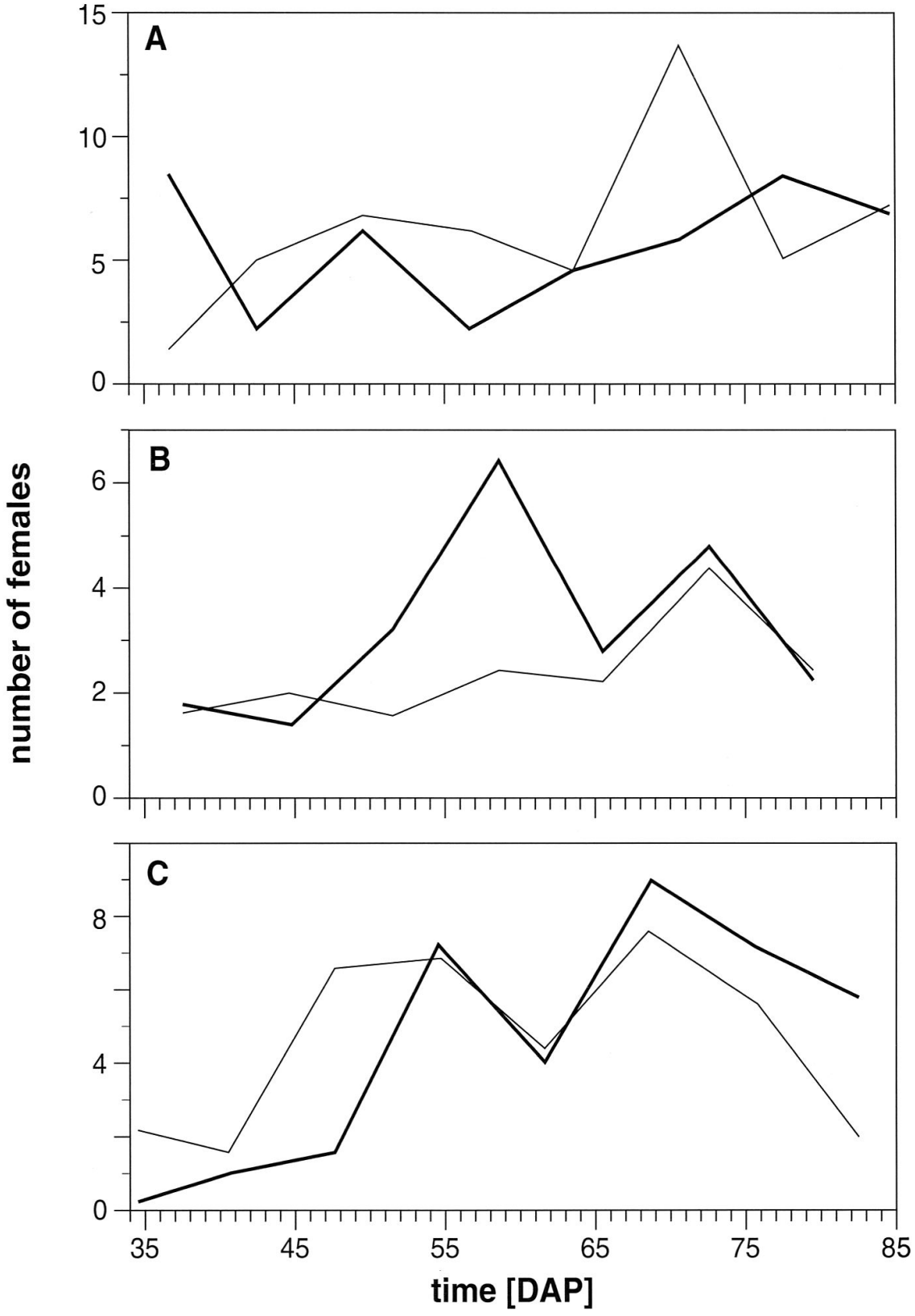

Fig. 8. Abundance pattern of *Megalurothrips sjostedti* adult females at Tchi-Ahomadegbe (Mono Department), for 3 fields planted during the 1st cropping season on 7/6/89 (A), 9/6/89 (B) and 12/6/89 (C). [cowpea varieties: Gbotogbongwe (——) and IT-82E-32 (——)].

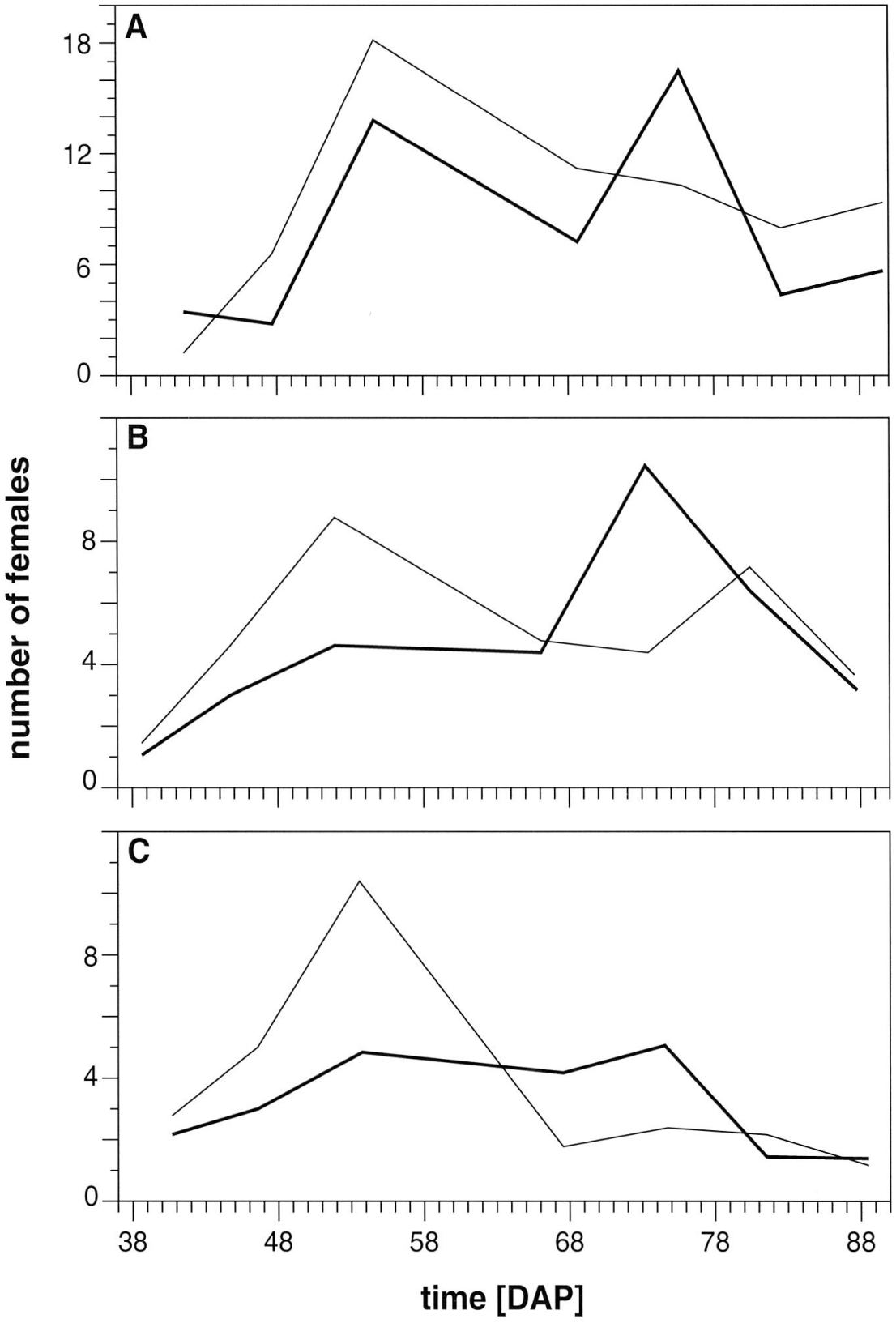

Fig. 9. Abundance pattern of *Megalurothrips sjostedti* adult females at Zouzouvou (Mono Department), for 3 fields planted during the 1st cropping season on 2/6/89 (A), 3/6/89 (B) and 5/6/89 (C). [cowpea varieties: Gbotogbongwe (——) and IT-82E-32 (▬)].

Sohedji (Fig. 10)

It has been shown in TAMÒ & BAUMGÄRTNER (1992) that the plant growth of the variety 'Kpodjiguégué' in this Central Western Benin locality was presumably limited by the poor soil fertility of the experimental field, where the other varieties considered in this experiment were also located. The thrips population per plant was about twice as high as in the previous localities but still below a level causing substantial damage.

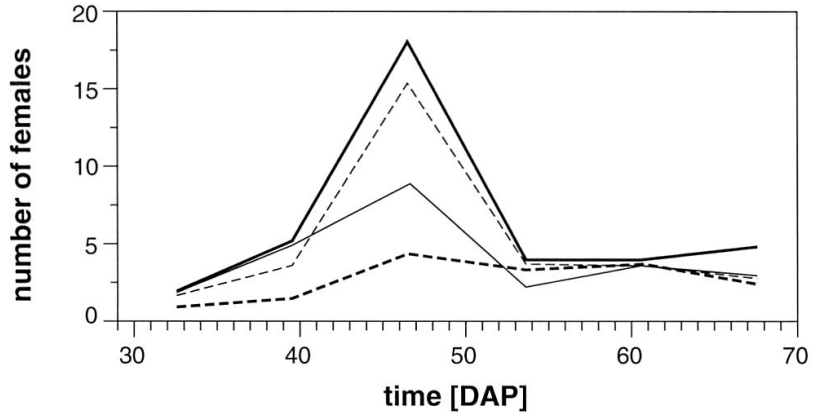

Fig. 10. Abundance pattern of *Megalurothrips sjostedti* adult females at Sohedji (Northern Zou Department), for a field planted during the 1st cropping season in 1989 [cowpea varieties: Kpodjiguégué (——) Gbotogbongwe (- - - -) IT-82E-32 (▬▬) and TVx3236 (▪▪▪▪)].

In agreement with TAYLOR (1969, 1974), the different infestation patterns in the two growing seasons are explained as follows. The adult females migrating into fields of the 1st season may have survived the dry season on a wide range of wild and, in minor proportion, cultivated alternate Leguminosae host plants, which offer different conditions for nutrition and reproduction (TAYLOR, 1974, TAMÒ *et al.*, 1992b). On the other hand, the origin of the population colonizing the fields in the 2nd season appears to be the 1st season plantings. This hypothesis is strengthened by the fact that most of the alternate hosts seldom flower during the rainy season where cowpea is cultivated.

In a particular field the fluctuations of the mean densities seem to be linked to changes in the population levels, which are more likely to be noticed if the population level is low, as in Fig. 7A for the 1st season. These fluctuations are partially explained by a greater sampling error incurring at low densities. However, the irregular flowering pattern of some cowpea varieties, or the sequence of thrips generations, as it seems to be the case in Fig. 7C, could also be responsible for the fluctuations.

In conclusion, the number of thrips present in a given area and ready to colonize a given field is controlling, by large, the infestation levels. Furthermore, the observations indicate that the varieties display different degrees of resistance (particularly TVx 3236, which had comparably less thrips in all fields sampled), but do not permit the identification of the functional resistance category. Nevertheless, the

link between infestation levels and oviposition substrates suggest that antixenosis (KOGAN & ORTMAN, 1978) rather than antibiosis (PAINTER, 1951) is the explanation for resistance. For TVx 3236, this hypothesis compares favorably with the studies of SALIFU *et al.* (1988a, b). The evaluation of resistance is furthermore rendered difficult by the activity of natural enemies which may have masked the plant effect on infestation pattern (TAMÒ *et al.*, 1992b). In addition, the observations appear to reveal different levels of tolerance to thrips attack which warrant further investigations. From a practical standpoint, and certainly in view of the priority given to both host plant resistance (SINGH *et al.*, 1990) and biological control (TAMÒ *et al.*, 1992b) for reducing yield losses due to *M. sjostedti*, the interactions between varieties with different levels of resistance and antagonists of *M. sjostedti* will be the object of further studies.

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ZUSAMMENFASSUNG

Die Verteilung der verschiedenen Entwicklungsstadien von *Megalurothrips sjostedti* (TRYBOM) auf der Augenbohne wurde mit unterschiedlichen Methoden zur Stichprobeentnahme untersucht: Schlupfkäfige für die Eier, Hitzeextraktion für die Larven und die Adulten, Klopfbrett und D-Vac für Adulte. Die Verteilung innerhalb der Pflanze konnte am besten durch ein Preferenzindex dargestellt werden, während die Verteilung zwischen den Pflanzen mit TAYLOR's Power Law analysiert wurde. Enumerative Stichprobenpläne wurden für die Klopfbrett- sowie für die D-Vac Methode entwickelt. Die Analyse der zeitlichen Verteilung über drei Jahre in vier verschiedenen Ortschaften in Benin zeigte tiefe Populationsdichten während der ersten Pflanzzeit, gefolgt von einer raschen Vermehrung während der zweiten Pflanzzeit. Die Befallsintensität war abhängig von der Anzahl Thripse, die am Anfang der Vegetationsperiode auf den verschiedenen Zwischenwirten vorhanden waren. Die untersuchten Augenbohnensorten wiesen unterschiedlich starke Resistenzen gegen *M. sjostedti* auf, die vermutlich auf Antixenose beruhen.

REFERENCES

AGYEN-SAMPONG, M., 1978. Pests of cowpea and their control in Ghana. *In*: SINGH, S. R., VAN EMDEN, H. F., & TAYLOR, T. A., (eds). *Pests of Grain Legumes: Ecology and Control*, pp. 85-92. Academic Press, London.

BIANCHI G., BAUMGÄRTNER, J., DELUCCHI, V., RHAHALIVAVOLOLONA, N., SKILLMAN, S., & ZAHNER, P., 1989. Sampling egg batches of *Maliarpha separatella* RAG. (Lep., Pyralidae) in Madagascan rice fields. *Trop. Pest Manage. 35:* 420-424.

CERUTTI, F., BAUMGÄRTNER, J., & DELUCCHI, V., 1988. Ricerche sull'ecosistema «vigneto» nel Ticino: I. Campionamento delle popolazioni di *Empoasca vitis* GOETHE (Hom., Cicadellidae, Typhlocybinae). *Mitt. Schweiz. Ent. Ges. 61:* 29-41.

CHESSON, J., 1978. Measuring preference in selective predation. *Ecology 59:* 211-215.

CHESSON, J., 1983. The estimation and analysis of preference and its relationship to foraging models. *Ecology 64:* 1297-1304.

EZUEH, M. I., 1981. Nature and significance of preflowering damage by thrips to cowpea. *Entomol. Exp. Appl. 29:* 305-312.

KARANDINOS, M. G., 1976. Optimum sample size and comments on some published formulae. *Bull. Ent. Soc. Amer. 22:* 417-421.

KOGAN, M., & ORTMAN, E. E., 1978. Antixenosis - a new term proposed to replace Painter's "Nonpreference" modality of resistance. *Bull. Ent. Soc. Amer. 24:* 175-176.

LEWIS, T., 1973. *Thrips: their biology, ecology, and economic importance.* Academic Press, London, 349 pp.

OJEHOMON, O. O., 1968a. The development of the inflorescence and extra-floral nectaries of *Vigna unguiculata* (L.) WALP. *J. W. Afr. Sci. Assoc. 13:* 93-111.

OJEHOMON, O. O., 1968b. Flowering, fruit production and abscission in cowpea, *Vigna unguiculata* (L.) WALP. *J. W. Afr. Sci. Assoc., 13:* 227-234.

PAINTER, R. H., 1951. *Insect Resistance in Crop Plants.* Macmillan & Co., New York, 520 pp.

RÖSINGH, C., 1980. *Untersuchungen über die Resistenz der Kuherbse, Vigna unguiculata (L.) WALP., gegen Megalurothrips sjostedti (TRYBOM) (Thysanoptera: Thripidae).* University of Hohenheim, 64 pp. (PhD thesis)

RUESINK, W. G., 1980. Introduction to sampling theory. *In*: KOGAN, M., &HERZOG, D.C., (eds). *Sampling methods in soybean entomology.* Springer Verlag, New York, 587 pp.

SALIFU, A. B., 1986. *Studies on aspects of the biology of the flower thrips, Megalurothrips sjostedti (TRYBOM) with particular reference to resistance in host cowpea, Vigna unguiculata (L.) WALP.* Wye College, University of London, 267 pp. (PhD thesis)

SALIFU, A. B., & SINGH, S. R., 1987. Evaluation of sampling methods for *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera: Thripidae) on cowpea. *Bull. Ent. Res. 77:* 451-456.

SALIFU, A. B., HODGSON, C. J., & SINGH, S. R., 1988a. Mechanism of resistance in cowpea, *Vigna unguiculata* (L.) WALP. genotype, TVx 3236 to the bean flower thrips *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera: Thripidae). 1: Ovipositional nonpreference. *Trop. Pest Manage. 34:* 180-184.

SALIFU, A. B., SINGH, S. R., & HODGSON, C. J., 1988b. Mechanism of resistance in cowpea, *Vigna unguiculata* (L.) WALP. genotype, TVx 3236 to the bean flower thrips *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera: Thripidae). 2: Nonpreference and antibiosis. *Trop. Pest Manage. 34:* 185-188.

SCHULTHESS, F., BAUMGÄRTNER, J. U., & HERREN, H. R., 1989. Sampling *Phenacoccus manihoti* in cassava fields in Nigeria. *Trop. Pest Manage. 35:* 193-200.

SINGH, S. R., & TAYLOR, T. A., 1978. Pests of grain legumes and their control in Nigeria. *In*: SINGH, S. R., VAN EMDEN, H. F., & TAYLOR, T. A., (eds.), *Pests of Grain Legumes: Ecology and Control*, pp. 99-111. London, Academic Press.

SINGH, S. R., JACKAI, L. E. N., DOS SANTOS, J. H. R., & ADALLA, C. B., 1990. Insect pests of cowpea. In: SINGH, S. R., (ed.), *Insect pest of food legumes*, pp. 43-89. John Wiley & Sons, Chichester.

SOUTHWOOD, T. R. E., 1978. *Ecological methods.* Chapman & Hall, London, 2nd ed., 524 pp.

TAMÒ, M., & BAUMGÄRTNER, J., 1992. Analysis of the cowpea *(Vigna unguiculata* WALP.) monocropping system in West Africa: I. A demographic model for carbon acquisition and allocation in cowpea. *Ecological Modelling 65:* 95-121.

TAMÒ, M., BAUMGÄRTNER, J., & GUTIERREZ, A. P., 1992a. Analysis of the cowpea (*Vigna unguiculata* WALP.) monocropping system in West Africa: II. Modelling the interactions between cowpea and the bean flower thrips *Megalurothrips sjostedti* (TRYBOM). *Ecological Modelling* (in press)

TAMÒ, M., BAUMGÄRTNER, J., DELUCCHI, V., & HERREN, H. R., 1992b. Assessment of three key factors responsible for the pest status of the bean flower thrips *Megalurothrips sjostedti* (TRYBOM) (Thysanoptera, Thripidae) in West Africa. (submitted to *Bull. Ent. Res.*)

TAYLOR, L. R., 1961. Aggregation, variance, and the mean. *Nature (London), 189:* 732-735.

TAYLOR, L. R., WOIWOOD, I. P., & PERRY, J. N., 1978. The density dependence of spatial behavior and the rarity of randomness. *J. Anim. Ecol. 47:* 383-406.

TAYLOR, T. A., 1969. On the population dynamics and flight activity of *Taeniothrips sjostedti* (TRYBOM) (Thysanoptera: Thripidae) on cowpea. *Bull. Ent. Soc. Nigeria 2:* 60-71.

TAYLOR, T. A., 1974. On the population dynamics of *Taeniothrips sjostedti* (TRYBOM) (Thysanoptera: Thripidae) on cowpea and an alternate host, *Centrosema pubescens* BENTH., in Nigeria. *Rev. Zool. Afric. 88:* 689-702.

VON ARX, R., BAUMGÄRTNER, J., & DELUCCHI, V., 1984. Sampling of *Bemisia tabaci* (GENN.) (Sternorrhyncha: Aleyrodidae) in Sudanese cotton fields. *J. Econ. Entomol. 77:* 1130-1136.

WILSON, L.T., & ROOM, P.M., 1983. Clumping patterns of fruit and arthropods in cotton with implications for binomial sampling. *Envir. Entomol. 12:* 50-54.

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