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Population dynamics of *Typhlodromalus limonicus* from Colombia, an introduced predator of the exotic cassava green mite in West Africa

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The introduction of *Typhlodromalus limonicus* (GARMAN & MCGREGOR) *sensu lato* is a major component of an on-going biological control campaign against the exotic cassava pest *Mononychellus tanajoa* (BONDAR) in Africa. However, long-term establishment of this exotic phytoseiid predator has not yet been achieved. The Colombian biotype of *T. limonicus* was evaluated as a biological control agent in Nigeria and Bénin by assessing its population response to selected abiotic and biotic factors. In field experiments, *T. limonicus* temporarily survived for ca. 19 generations during wet and dry seasons. *T. limonicus* population densities were negatively correlated with that of *M. tanajoa* suggesting its predation potential on *M. tanajoa.* The spider mite populations were positively while the predatory mite populations were negatively affected by the low (< 50%) relative humidity during the dry season. Competition with endemic phytoseiid species on cassava was not evident. *T. limonicus* was present on top leaves with *M. tanajoa,* whereas indigenous predators were more frequent on bottom leaves. Alternate prey may play a role in sustaining *T. limonicus* populations during times of prey scarcity. Biotypes of a potential biological control agent for *M. tanajoa* should be selected to improve the chances of a successful establishment in Africa.

INTRODUCTION

The Cassava Green Mite, *Mononychellus tanajoa* (BONDAR) (Acari: Tetranychidae), has become an important pest in African cassava fields since its accidental introduction in the early 1970s (NYIIRA, 1972; LYON, 1974). In the Neotropics where it originated, *M. tanajoa* is controlled by a large complex of natural enemies (BYRNE *et al.,* 1983; BELLOTTI *et al.,* 1987). However, efficient natural predators are absent in Africa (NYIIRA & MUTINGA, 1977; YANINEK *et al.,* 1987, 1989), allowing *M. tanajoa* populations to increase tremendously during the dry season (LEUSCHNER, 1980; AKINLOSOTU, 1982; YANINEK *et al.,* 1987). This results in yield losses of 10–80% (LYON, 1974; SHUKLA, 1976; NYIIRA, 1978; YANINEK & HERREN, 1988; YANINEK *et al.,* 1990).

Predatory mites of the family Phytoseiidae have been long associated with tetranychid mites on cassava in the Neotropics (BYRNE *et al.,* 1983, BELLOTTI *et al.,* 1987). The ability of phytoseiids to control mite pests is well documented (HUFFAKER *et al.,* 1970; MCMURTRY, 1982, 1983; MCMURTRY *et al.,* 1970). One of the most frequently recorded and widely distributed phytoseiid species associated with *M. tanajoa* in the neotropics is *Typhlodromalus limonicus* (GARMAN & MCGREGOR) *sensu lato* (Acarina: Phytoseiidae). It is reported in areas with moderate to high annual rainfall (700 to > 1200 mm) and a moderate to long dry season (3 to 6 months) and is closely associated with *M. tanajoa* (BELLOTTI *et al.,* 1987; MORAES, 1987). Using exclusion experiments, BRAUN *et al.* (1989)

demonstrated that *T. limonicus* significantly reduced *M. tanajoa* in cassava fields. While some work has been done to evaluate the bionomics and olfactory responses of *T. limonicus* to *M. tanajoa* (JANSSEN *et al.*, 1990), there is little information on the phenology of this exotic phytoseiid species on cassava in Africa where the introduction of exotic phytoseiids is considered as an ecologically sound approach to control *M. tanajoa* (YANINEK & HERREN, 1988; YANINEK *et al.*, 1989).

The objective of this study was to investigate the influence of weather and selected biotic factors (competition, within-plant distribution, and alternate food sources) on the population dynamics of *T. limonicus* in the field. Thus the potential of *T. limonicus* as a biological control agent was evaluated by focusing on its ability to survive and to reduce *M. tanajoa* populations in the field.

MATERIALS AND METHODS

T. limonicus was received from the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia. Several biologically distinct biotypes of *T. limonicus* have recently been identified in the neotropics. In this study, results refer only to a biotype of *T. limonicus* obtained from near the campus of the CIAT.

Data on population dynamics of *T. limonicus* and on possible prey were collected from a cassava field at the International Institute of Tropical Agriculture (IITA) in Cotonou, Bénin. Preliminary experiments in a tent were conducted at IITA in Ibadan, Nigeria. No control plots were sampled in Ibadan. In both locations, twenty-five 8-months old plants of a 80 × 30 m field of cassava (IITA cultivar : TMS 91934), planted on ridges at a density of 1 × 1 m, were covered with a nylon gauze tent (600 × 600 × 280 cm; mesh opening : 200 μm). The tent prevented casual immigration of endemic natural enemies of which phytoseiids were the smallest predator of concern. The plants were pruned to obtain a single stem and trimmed initially of all but the first upper 25 leaves. The plants did not touch each other. Natural pyrethrum (1.6 ml/250 ml H_2O) was applied to plants inside the tent to eliminate all possible predatory mites and potential prey. Two weeks after spraying, 2 leaves per plant were sampled to assess the impact of the insecticide on the mite populations. The plants were then infested with 10 *M. tanajoa* adult females per leaf on May 26, 1988 and on March 1, 1989 at Ibadan and Cotonou, respectively. One week later, 625 *T. limonicus* females, of mixed ages, were released at a density of one per leaf at Ibadan. At Cotonou, predator releases were conducted on April 11, 1989. Females were individually transferred in closable centrifuge-tubes (length: 30 mm, diameter: 7 mm) and attached to the leaves. In order to assess the effect of the tent on the population dynamics of *T. limonicus* in the field the Cotonou trial included two additional plots without tent. Predator releases were made in one of these plots, the other was used as a control.

Population counts of all mites (phytoseiids, tetranychids) and the presence/absence of potential prey (whiteflies, thrips, cassava mealybugs and collembola), were made weekly (twice a week for the first 2 months in Ibadan). Five leaves per plant, 3 in the higher part, 2 in the lower part of the foliage, were examined (non-destructive method) for all active stages of *T. limonicus* and adult stages of *M. tanajoa* using a microscope mounted on a tripod stand for field observations. The 9 central plants of the tent plot were monitored from June 1988 to January 1989 in Ibadan and likewise from April to August 1989 in Cotonou. Samples of 3 phytoseiids per plant were collected every month, mounted and identified to determine the level of contamination by indigenous phytoseiid species.

The weather records were taken at IITA's central weather stations in Ibadan and Cotonou and at field stations in the tents. The daily mean temperature and relative humidity were calculated by using the following formula: (Tmp/RH at 7 am + Tmp/RH at 2 pm + [2 × Tmp/RH at 9 pm])/4. The difference in the climate between the tent and the field situation was as follows: radiation and rainfall in the tent were reduced by about one fourth. The daily mean temperature and the relative humidity were slightly higher in the tent, + 1.5 °C and + 2%, respectively.

RESULTS

Preliminary Ibadan field-trial

After the application of pyrethrum, the plants in the tent were free of indigenous phytoseiids.

The average daily temperature for the total observation period was 24.9 ± 1.3 °C with an absolut minimum-maximum range between 15.0 and 34.2 °C. The average relative humidity was 84 ± 12%. Rainfall totaled 1246.1 mm during the experiment with a maximum of 89.3 mm on one day (Fig. 1a). During the harmattan (a period during the dry season characterized by low relative humidity and fine dust due to prevailing winds from the sahel region) in December, the relative humidity averaged 51 ± 15% (minimum of 16% and a maximum which did not exceed 40% for several days) and the temperature averaged 23.9 ± 1.0 °C.

The *M. tanajoa* population in the field tent (Fig. 1c) declined from 27 to 1.2 adults per leaf within 2 weeks after the release of *T. limonicus* and remained low during the remainder of the wet season (0–0.9 adults per leaf). Following the wet season, *M. tanajoa* increased steadily reaching a level of 45 adults per leaf by the last sampling date in the dry season during the harmattan episode.

The phytoseiids increased steadily (Fig. 1c) from 1 to 6.3 actives per leaf in August. After a small decline in predator numbers during the later part of August, the population increased to 5.4 actives per leaf by the end of September. A sharp decline in phytoseiid densities (0.5 actives per leaf) followed during the transition from wet to dry season in late October. Phytoseiid densities again increased during the subsequent dry season reaching 6.6 actives per leaf (Fig. 1 c). However, this latter increase coincided with an increase in the level of contamination by local phytoseiid species (25 to 100% by the last sampling date) (Fig. 1 b). In order of abundance, the local phytoseiid species were *Euseius fustis* (PRITCHARD & BAKER) (90% of the specimens), *T. saltus* (DENMARK & MATTHYSSE) (9%) and *Amblyseius rykei* (PRITCHARD & BAKER) (1%). The phytoseiids declined more than 15-fold (3.5 to 0.2 actives per leaf) within a one-week period during the harmattan episode (Fig. 1 c). *T. limonicus* survived and reproduced for approximately 19 generations (at 9 days for egg to egg development at 25 °C [H. ROGG, unpubl. data]) before extinction.

Other arthropods found with *M. tanajoa,* which were potential alternate prey for *T. limonicus* were whiteflies, *Bemisia tabaci* (GENNADIUS), collembola (unidentified), cassava mealybugs, *Phenacoccus manihoti* (MAT.-FERR.), thrips (unidentified), and red spider mites, *Oligonychus gossypii* (ZACHER). Only whiteflies and collembola were present continuously.

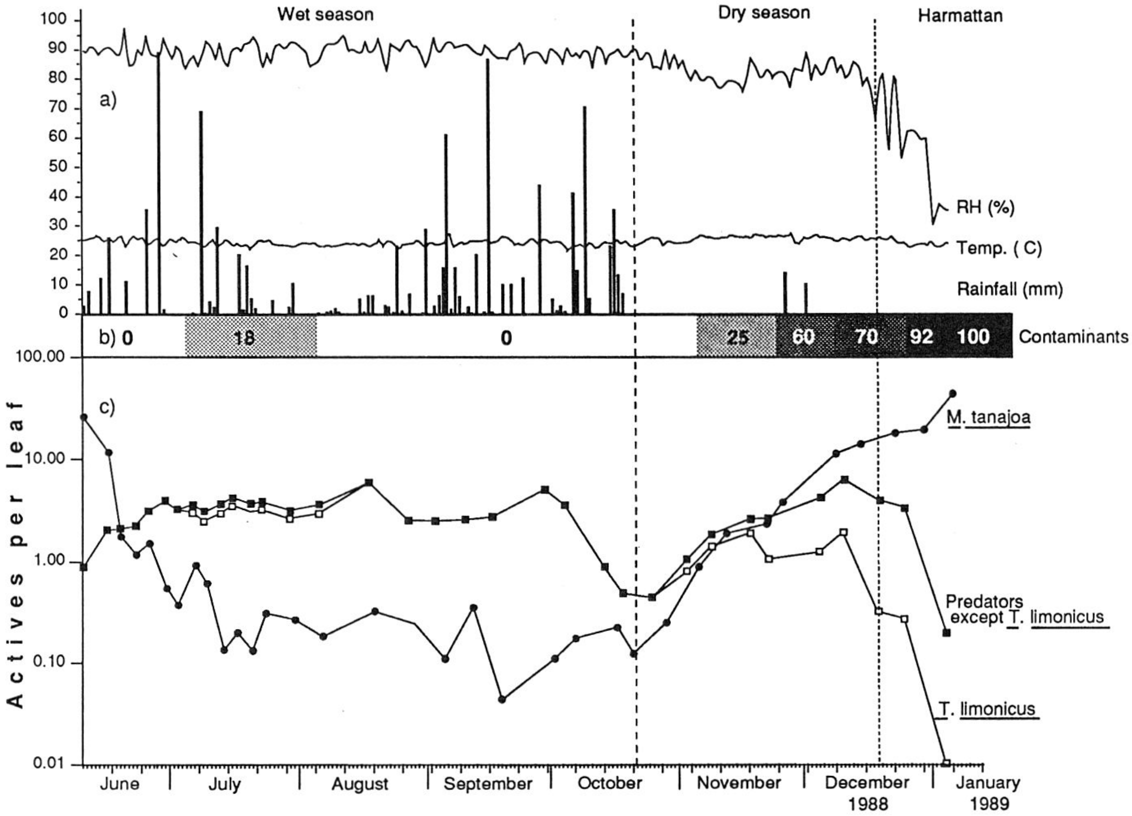

Fig. 1. a) Ibadan weather records from June, 1988 to January, 1989 with the calculated daily ambient temperature, relative humidity, and the daily rainfall from the IITA central weather station at Ibadan.
b) Contamination with native phytoseiids (in %).
c) Population dynamics of active stages of *T. limonicus* and adult stages of *M. tanajoa* per leaf under tent conditions at Ibadan.

Cotonou field-trial

After the application of pyrethrum in the tent and in the field plots control samples did not reveal any native predatory mites.

The observation period in Cotonou covered the wet season only (Fig. 2a). The daily temperature for the total experimental period averaged 24.2 ± 1.5 °C with a range between 18.0 to 31.0 °C. The average daily relative humidity was 86 ± 4% (range 52 to 98%). The rainfall totaled 587.9 mm during the field trial with a maximum of 56.1 mm on one day.

M. tanajoa densities in the tent (Fig. 2c) declined from 119 to 8 adults per leaf within 6 weeks after the release of *T. limonicus*. A similar decline but of much less magnitude was recorded in the field release plot, from 5 to 0.5 adults per leaf (Fig. 2d). *M. tanajoa* in the tent peaked at 23 adults per leaf in August, whereas *M. tanajoa* in the field release plot declined to below 1 adult per leaf by mid-May and remained below 0.5 adults per leaf before becoming extinct in July.

M. tanajoa in the control plot also decreased throughout this period, but the rate of decline was relatively low once a density of about 1 active per leaf was reached and until this population finally dropped to zero by the beginning of August (Fig. 2e).

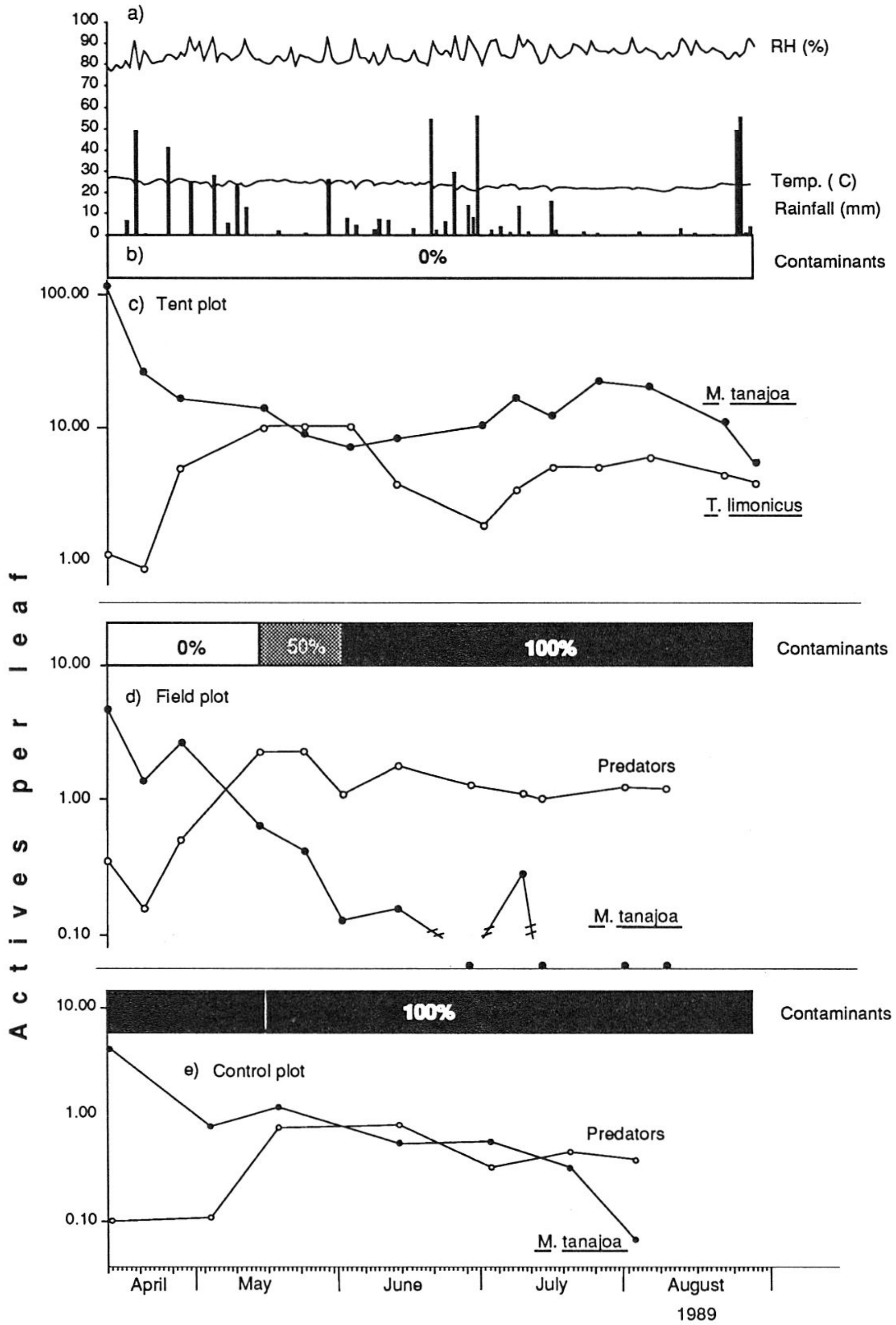

Fig. 2. a) Cotonou weather records from April to September, 1989 with the calculated daily ambient temperature, relative humidity, and the daily rainfall from the IITA central weather station at Cotonou.
b) Contamination with native phytoseiids (in %).
c) Population dynamics of active stages of *T. limonicus* and adult stages of *M. tanajoa* per leaf under tent plot conditions at Cotonou.
d) Population dynamics of active stages of *T. limonicus* and adult stages of *M. tanajoa* per leaf under field plot conditions at Cotonou.
e) Population dynamics of active stages of native phytoseiids and adult stages of *M. tanajoa* per leaf under control plot conditions at Cotonou.

Five weeks after release, the phytoseiids in the tent plot increased 10-fold from 1 to 10 actives per leaf (Fig. 2c), and to 2 actives per leaf in the field plot

(Fig. 2d). The number of phytoseiids in the control plot, all individuals of the indigenous species *E. fustis,* never exceeded 1 active per leaf (Fig. 2e). Following a modest decline, the population of predators in the tent reached a plateau of approximately 5 actives per leaf during August (Fig. 2c). *T. limonicus* survived and reproduced in the tent for about 15 generations. However, in the field, *T. limonicus* went extinct after about 8 generations. There was no contamination by local phytoseiids in the tent during the experiment (Fig. 2b). By contrast, in the field plot, contamination by *E. fustis* (50%) began 4 weeks after the release of *T. limonicus* (Fig. 2d). The predator population in the field release plot was contaminated 100% by *E. fustis* by June (Fig. 2d).

Only whiteflies and *Oligonychus gossypii* were recorded as potential alternate food sources in the tent and field plots. Whiteflies were present continously both in the tent and the field, whereas *O. gossypii* was only recorded in the tent.

The stratified samples revealed a significantly higher number of *T. limonicus* and *M. tanajoa* in the upper part of the plant than in the lower foliage in the tent except for one sample date ($p < 0.05$) (Fig. 3a). The population densities for the strata levels for both *M. tanajoa* and predators were similar in the field plot (Fig. 3b).

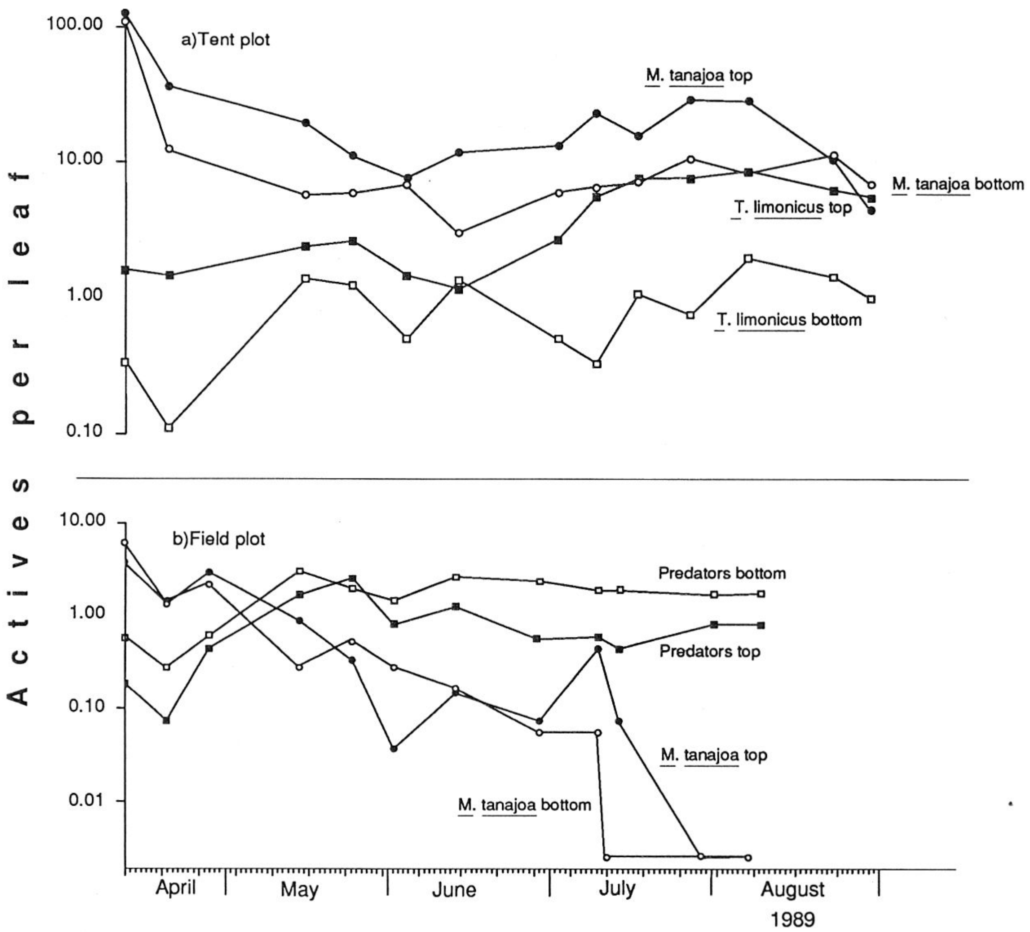

Fig. 3. a) Density of active stages of *T. limonicus* and adult stages of *M. tanajoa* per leaf found on top and bottom leaves under tent plot conditions at Cotonou.
b) Density of active stages of *T. limonicus* and adult stages of *M. tanajoa* per leaf found on top and bottom leaves under field plot conditions at Cotonou.

DISCUSSION

Climate factors play a role in the population dynamics of most mites (Van de Vrie *et al.*, 1972). Samways (1979) in Brazil and Yaninek *et al.* (1989) in Nigeria showed that rainfall was a key factor in the mortality of *M. tanajoa*. In this study, it is difficult to attribute the decline in *M. tanajoa* in the field to either rainfall or predation by *T. limonicus* since the initial mite numbers in the field were low from the beginning. In the tent, however, rainfall was probably only a minor mortality factor since the screen material absorbed most of the kinetic energy of the raindrops (H. Rogg, unpubl. data). Low relative humidity favors most spider mite populations but suppresses most phytoseiid populations (Linke, 1953; Boudreaux, 1958; Stenseth, 1979; Van Dinh *et al.*, 1988). The Cotonou experiments were performed during the wet season therefore low relative humidity effects were not evident. In the preliminary trials at Ibadan, however, *T. limonicus* densities decreased whereas *M. tanajoa* populations increased during the harmattan indicating a correlation with low relative humidity.

A wide variety of biotic factors are also important in regulating pest mite population densities (McMurtry & Johnson, 1966; Huffaker *et al.*, 1970). This Colombian biotype of *T. limonicus* has already been shown to significantly reduce *M. tanajoa* populations in its area of origin (Braun *et al.*, 1989). The predator in this study was negatively correlated with *M. tanajoa* densities, particularly during the first few weeks after release suggesting a direct interaction between *T. limonicus* and *M. tanajoa*. The persistence of *T. limonicus* during periods when *M. tanajoa* prey were scarce implies that alternate food sources may be important in sustaining the predator during critical periods. The presence of alternate prey helps stabilize the interaction between the predators and its prey. Since the alternate prey were recorded qualitatively, the relative importance of each is unknown. However, laboratory experiments have shown that *T. limonicus* survived on a variety of non-tetranychid prey foods, such as thrips eggs and larvae, whitefly eggs and nymphs, and plant products, such as pollen and exudate (Oduor, 1988; H. Rogg, unpubl. data). Plant effects on the mite populations growth such as leaf age and quality were examined by Gutierrez *et al.* (1988).

The spatial association between a predator and its prey may be an indication of specificity. In this study we found a spatial association between *T. limonicus* and *M. tanajoa* on the young leaves of the plant where relative few indigenous phytoseiids were found. This was most evident in the tent experiment in Cotonou where contamination with local phytoseiids was avoided and relatively dense populations of *T. limonicus* developed. In the Neotropics, phytoseiids were reported to live and oviposit among the spider mite colonies and prey on all prey stages indicating a coevolution in the spatial association between predator and prey (Bellotti *et al.*, 1987).

Competition with the endemic phytoseiid species could be the reason *T. limonicus* failed to become established in the field. The only evidence of competition, however, was the disappearance of the exotic predators in the presence of endemic phytoseiid species in the tent in Ibadan and in the field in Cotonou. In the tent in Cotonou, *T. limonicus* was found much more often on top than on bottom leaves, while in the field, local species were found more often on bottom than on top leaves. This implies that competition for *M. tanajoa* was not likely the reason for the disappearance of *T. limonicus* neither in the preliminary tent trial in Ibadan nor in the field in Cotonou. The endemic predators in the Ibadan tent plot seemed to be unable to keep *M. tanajoa* populations from increasing at any time of the observation period. The spatial separation between indigenous phytoseiids and *M. tanajoa* in Africa may help explain their inability to control this exotic mite pest.

The Colombian biotype of *T. limonicus* tested in this study may not be suitable for introduction given the local conditions. Abiotic and biotic constraints appeared to have prevented establishment in the field, although *T. limonicus* survived and reproduced under tent conditions for several generations before going extinct. The rapid extinction in the field may simply reflect the rapid dispersal of the predator searching for suitable environmental conditions.

Successful control of *M. tanajoa* in Africa may require the selection of a biological control agent according to regional biotypes. MEYERDIRK & COUDRIET (1986) showed that biotypes of *Euseius scutalis* (ATHIAS-HENRIOT) from different geographical locations responded differently to *Bemisia tabaci.* Recent introductions of biotypes of *T. limonicus* from coastal areas in Colombia and Brazil revealed significant differences in response to the local conditions in Cotonou. There is probably no single superior phytoseiid biotype for Africa. Therefore, emphasis should be placed on choosing areas in the Neotropics where selection of potential biotypes for importation can be made to conform to specific agrometeorological zones in Africa (YANINEK & BELLOTTI, 1987).

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RÉSUMÉ

L'introduction de *Typhlodromalus limonicus* (GARMAN & MCGREGOR) *sensu lato* est actuellement la composante majeure d'une campagne de lutte biologique contre le ravageur exotique du manioc, *Mononychellus tanajoa* (BONDAR) en Afrique. Jusqu'à ce jour cependant, il n'a pas encore été possible d'établir de manière durable ce phytoséiide temporairement survécu aux saisons pluvieuses et sèches pendant 19 générations environ. Les densités de population de *T. limonicus* étaient négativement corrélées avec celle de *M. tanajoa* ce qui laisse entrevoir le potentiel de prédation de *T. limonicus* sur *M. tanajoa.* La faible humidité relative (< 50%) au cours de la saison sèche a eu un effet positif sur les populations d'acariens ravageurs, alors qu'elle a négativement affecté les populations d'acariens prédateurs. La compétition avec les espèces endémiques de phytoséiides n'a pas pu être observée de façon manifeste. *T. limonicus* était présent sur les feuilles apicales en compagnie de *M. tanajoa,* alors que les prédateurs indigènes étaient plus fréquents sur les feuilles basales. Il se peut que les proies alternatives contribuent à soutenir les populations de *T. limonicus* quand les proies sont rares. Des biotypes d'un agent potentiel de lutte biologique contre *M. tanajoa* devraient être sélectionnés afin d'augmenter les chances d'établissement de cet agent en Afrique.

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