foliage condition is, therefore, a critical determinant of rate of migration and dispersal.

Many factors are involved in regulating mite populations. However, the data presented in Fig. 1 suggest that different varieties of cassava support different population densities even when other conditions are similar. This variation in the intensity of infestation and, therefore damage, suggests that certain varieties are preferred. This preference would suggest breeding cassava varieties that are resistant or tolerant to the green cassava mite. We favour breeding fast-maturing varieties that are resistant/tolerant to *M. tanajoa* as the most effective control measure (Nyiira 1975c).

Oligota species in Uganda appear in synchrony with *M. tanajoa*. Table 2 shows, however, that during heavy infestation by the host mite when the population of the latter is about to start diminishing, the population of the predator falls rapidly. This allows a rapid buildup of the host mite to migrate to fresh leaves before the predator population builds up again. However, the reappearance of *Oligota*, and the combined relative effectiveness of other predators of the host mite, appear to keep down mite populations. An integrated program utilizing fast-maturing resistant/tolerant varieties backed by a viable program of biological control was suggested by Nyiira (1975a). Bennett (1975) and Bennett and Yaseen (1975) obtained useful data on correlations of *Oligota* and phytoseiid predatory mites with *M. tanajoa* populations in Trinidad. They have reported variations in the abundance of the predators. Their results probably explain the total effect of predators on the green cassava mite, an effect not otherwise explained when individual predators are considered.

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Distribution, Biology, and Population Dynamics of the Green Cassava Mite in the Neotropics

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Investigations on the biology and ecology of the green cassava mite *Mononychellus tanajoa* and its natural enemies, as well as those of other cassava mites, to evaluate the latter for trial in Africa have been conducted in the Neotropics since April 1974 by the Commonwealth Institute of Biological Control, Trinidad. In Trinidad, densities of *M. tanajoa* are closely related to rainfall; dry periods are conducive to the development of high mite populations. The age and physiological condition of the host plant also greatly influence mite densities. Mite dispersal is influenced by wind. Regular observations on several cassava varieties during 1975 did not indicate any of these to be resistant to mite attack.

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Predators play a significant role in regulating population densities of the mite. Of the several predators recorded, *Oligota minuta*, the dominant predator, and *Typhlodromalus limonicus* and *T. rapax*, two important predaceous mites, merit introduction against *M. tanajoa* in Africa.

The Neotropical green cassava mite *Mononychellus tanajoa* was reported recently from Uganda (Nyiira 1972). The mite spread rapidly and is already causing serious damage in several parts of the Ethiopian region of Africa. Heavy infestations result in retarded plant growth and leaf shedding (Lyons 1973). Because chemical control under African conditions is not practical, other measures including biological control are being studied.

As *M. tanajoa* is not considered a serious pest in the Neotropics very little information is available about the mite and its predators. Investigations on the biology and ecology of the mite and its natural enemies, as well as those of other cassava mites, to evaluate the latter for trial in Africa were initiated at this laboratory in April 1974. The results obtained to date are presented here.

Investigations and Results

Distribution of M. tanajoa

The mite occurs in Brazil (Bondar 1938) and Paraguay (Aranda and Flechtmann 1971), and is now widespread in Trinidad and Guyana. It is also abundant in Colombia and probably occurs in Surinam and Venezuela.

Other Mites

Surveys have been carried out for cassava mites and their natural enemies in several areas in Central and South America and the Caribbean, and several other tetranychids infesting cassava were encountered. While special visits were made to survey for cassava mites in Colombia, Mexico, Panama, and Peru, other records were obtained from Antigua, the Bahamas, Barbados, Guatemala, Jamaica, Montserrat, Nicaragua, St. Kitts, and Surinam in connection with other work. Records of *M. tanajoa* and other tetranychids on cassava encountered during the surveys are given in Table 1.

Of the three tetranychids attacking cassava in Trinidad, *M. tanajoa* belongs to the *caribbeanae* group characterized by Paschoal (1971), and can be easily recognized. Both *T. tumidus* and *T. urticae* females are carmine but the former is easily separated by the well-developed mediodorsal spur on the empodium which is tiny or absent from *T. urticae* (Pritchard and Baker 1955). *T. tumidus* is usually a greenhouse pest while *T. urticae* attacks senescent leaves with depleted nutrients. *M. tanajoa* is not common on such plants.

Biology

The biology of *M. tanajoa* was investigated in the laboratory (temperature 26.8±2.2 °C and relative humidity of 82% in the morning to 55% in the afternoon). The preoviposition period lasted 1–2 days. The duration of the egg, larval, protonymphal and deutonymphal stages were 3–4, 1–2, 1–2 and 2–3 days, respectively. Each active stage was followed by a quiescent stage lasting less than a day and the total egg to adult period was 11–13 days. The males which mature first remain near the female teleochrysalis ready to mate with the emerging females. Females laid 21–65 (avg 38.5±15.8) eggs during 8–14 days; they lived up to 18 days.

Under field conditions eggs are laid singly on the sides of the midrib or other veins or in concavities on the lower surface of the leaf. Most of the eggs are laid on the basal half of the leaf.

Population Studies

Regular observations from April 1974 to date have shown that densities of *M. tanajoa* are closely related to the pattern of rainfall. In Trinidad the average daily temperatures do not fluctuate greatly during the year. The annual rainfall varies from 2100 to 2500 mm. The main rainy season extends from the end of May or early June to December or mid January; about 80% of the annual precipitation occurs from middle of July to December despite a comparatively dry period of 4–5 weeks in September–October. The relative humidity varies from about 80% in the morning to about 55% in the afternoon during the dry season and remains generally high, around 90%, during the wet season.

Data, based on weekly counts, indicate that dry periods are conducive to the development

Table 1. Tetranychids collected on cassava during surveys in 1974–75 (localities in parentheses).[a]

Tetranychids	Distribution
Mononychellus (Eotetranychus) caribbeanae (McGregor)	Barbados, Nicaragua (Carazo), Panama (Aquadulce), Peru (Chiclago), St. Kitts (Sandy Point) and Bahamas (Andros)
M. mcgregori (Flechtmann and Baker)	Colombia (Jamundi)
M. tanajoa (Bondar)	Brazil (State of Bahia), Colombia, Guyana (Georgetown), Paraguay and Trinidad
Oligonichus peruvianus	Colombia (Cauca Valley)
Tetranychus cinnabarinus (Boisduval)	Montserrat, W.I.
T. tumidus (Banks)	Mexico (Yucatan State) and Trinidad
T. urticae (Koch)	Colombia (Cauca Valley), Peru (La Molina and Mala) and Trinidad
T. sp. probably *urticae*	Colombia (Palmira) and Peru (Mala)
Tetranychus sp.	Bahamas (Andros Island), Mexico (Yucatan State) and Nicaragua (Granada)

[a]See Flechtmann and Baker (1970) and Jeppson et al. (1975) for additional distribution and host records.

of high mite populations. Mite populations showed upward trends in March–April and developed peak levels by the end of May or early June which persisted to the middle of July when they dropped suddenly with the onset of heavy rains. A minor peak developed during the short dry period in September–October. Weekly counts on 10 cassava varieties in an experimental plot during 1975 indicated that 56.1–66.5% of the mite population occurred in June–July during the major peak level and 9.0–29.7% in September–October during the short-lived minor peak. Sustained heavy rains in October were catastrophic. As *M. tanajoa* does not form a protective web all stages including the eggs were dislodged by sustained heavy rain and the mite was scarce throughout the remainder of the wet season.

The age and physiological condition of the host plant also influenced mite densities. Very young plants usually harboured few mites; the few newly flushed leaves not only provide only small surface areas but the nutrients are not fully synthesized. Similarly very old plants with depleted nutrients and retarded growth did not provide favourable conditions. Young vigorous plants about 4–8 months old, which produce new leaves early in the dry season, provide very favourable conditions for the development of heavy mite populations.

Most of the mites occur on the upper leaves of the plant, the largest numbers being on leaves 5–10; the top 3–4 newly flushed leaves carry few mites. After the tenth leaf the numbers fall sharply apparently due to the depletion of nutrients.

Several tetranychids disperse under the influence of wind (van deVries et al. 1972). Female mites suspend themselves on silken threads and are carried away by wind currents. This activity usually occurs during the hot and comparatively calm periods between 9 and 10 AM and 3 and 4 PM when the wind speed is below 5 mph. In an experimental plot the mite dispersed over a distance of 200 m in the direction of the prevailing wind between 1 May and 23 July 1975.

Montaldo (1972) reported cassava varieties resistant to tetranychids in Venezuela. Also Nyiira (1972) noticed varying levels of *M. tanajoa* infestations and differing degrees of susceptibility related to cassava varieties in Uganda. Regular counts were made on four cassava varieties from May to September 1974 and, while different levels of infestations were noticed, the results were inconclusive because the plots of the different varieties were in different rainfall zones. In a special plot with 10 local varieties at Curepe weekly counts of mites from March 1975 to February 1976 indicated that none of these varieties was entirely resistant to mite attack. However, significant differences in mite densities on some varieties were recorded during the periods of peak populations. While variety Maracas Black Stick had the lowest levels during both the

Table 2. Predators of *M. tanajoa* and related cassava mites encountered during surveys in the neotropics, 1974–75.

Predator	Distribution
Phytoseiidae	
Euseius hibisci (Chant)	The Bahamas (Andros Island)
Phytoseuilus macropilis (Banks)	Peru (Mala)
Typhlodromalus limonicus (Garman and McGregor)	Colombia (Cali), Mexico (Oaxaca State) and Trinidad
T. rapax (DeLeon)	Colombia (Palmira) and Trinidad
Cecidomyiidae	
Feltiella sp.	The Bahamas and Montserrat
Unidentified	Barbados, St. Kitts, and Trinidad
Feltia sp.	Mexico (Tapachula-Chinapo)
Coccinellidae	
Stethorus sp.	Nicaragua, Trinidad, and Colombia
Staphylinidae	
Oligota barbadorum (Frank)	Barbados
O. centralis (Sharp)	Colombia, Mexico and Peru
O. minuta (Cam.)	Antigua, the Bahamas (New Providence and Andros Island), Colombia, Montserrat, Peru, and Trinidad
Thysanoptera	
Unidentified	Trinidad

major and the minor peak populations the other varieties were not very consistent.

Natural Enemies

While spider mites are regularly attacked by predators they have no arthropod parasites. Predators belonging to the families Phytoseiidae, Cecidomyiidae, Coccinellidae, Staphylinidae, and a thysanopteran in association with cassava mites were encountered during surveys in the Neotropics (Table 2).

Both qualitative and quantitative data on the predators of cassava mites were obtained by regular sampling in several fields as well as in plots especially set up for this purpose in Trinidad. Elsewhere surveys were brief and qualitative data only were obtained.

Oligota minuta is the dominant predator of *M. tanajoa* in Trinidad. Eggs are deposited on the lower surface of the leaf. Eggs are laid amongst the mite infestations; only a few are laid next to the veins. Small larvae prefer host eggs but the second- and third-stage larvae which consume the most prey, as well as the adults, feed on eggs and all active stages of the host.

Fluctuations in populations of this staphylinid were correlated with those of the host. Regular counts from April 1974 to March 1976 showed that it was scarce or absent from cassava when mite infestations are very low during July to late February. It appears in March when the mite commences to increase and it becomes abundant when host populations reach peak levels in May to July. The abundance is highly correlated with the mite densities on individual plants with the largest numbers occurring on heavily infested plants. The numbers of the predator also vary in relation to the infestation levels on leaves of individual trees; larger numbers were encountered on leaves 6–10, the largest numbers occurring on leaves 7 or 8 where adults and large nymphs of the mite are usually most abundant. Adults are usually more abundant on densely infested leaves in the early morning hours than during the hotter period between 10 AM and 5 PM.

Regular counts in experimental plots of cassava varieties in 1975 indicated differences in the predator population correlated more closely with host densities than with variety of cassava; larger numbers were encountered on the varieties Black Stick and Brown Stick which harboured higher mite populations than on variety Maracas Black Stick which had few mites. Black Stick had the highest mite density (158.9/leaf) and also the largest predator population in June. It showed a lower host density in July while on Brown Stick, which had comparatively fewer mites and fewer staphylinids in June, an increase in mites occurred in July. This suggests that when abundant the staphylinid suppresses mite populations. During periods of scarcity of mites on cassava *O. minuta* migrates to plants infested with other spider mites.

The two phytoseiid mites *Typhlodromalus limonicus* and *T. rapax* are regularly associated with *M. tanajoa* on cassava in Trinidad. Eggs of both species are laid amongst the mites even when infestations are light. Adults and nymphs actively prey on the eggs and active stages of *M. tanajoa*; when not feeding they rest for long intervals concealed either along the mid-rib or on the petiole.

The phytoseiids are most abundant during the peak levels of the host mite population but they are seldom as abundant as *Oligota* and their intrinsic rate of increase appears to be lower than that of *M. tanajoa.*

The undetermined cecidomyiid appeared only during periods of peak mite densities and then only in negligible numbers. *M. tanajoa* does not seem to be its preferred host as larvae are more abundant on infestations of the carmine mite on other hosts. Larvae of the predatory thrips occasionally preyed on host eggs and the active stages of *M. tanajoa* but adults were seldom observed on cassava. The occurrence of *Stethorus* sp. was sporadic even during peak levels of *Mononychellus* which does not seem to be its regular prey.

Effects of Pesticides

The effects of Galecron and Malathion were studied in a cassava plot at the Experimental Station of the University of the West Indies during June 1975 to January 1976. Initially the plot was treated with Galecron (2.2 g/gal). While the mite was suppressed initially after the treatment its resurgence was rapid and additional treatments were required every 3–4 weeks. In August this acaricide was replaced by Malathion but its effectiveness did not extend beyond 2 weeks and the plot was sprayed every 15–18 days to keep mite populations at a low level.

The mite populations in the untreated plot exhibited the normal pattern of seasonal incidence (2691 in June, 355 in November, 1077 in January) observed elsewhere and the predatory fauna persisted throughout the period. In the treated plots the frequency of sprays did not give the predators sufficient time to recover. While *Oligota* and also the cecidomyiid predator appeared to a minor extent with the resurgence of the mite in June–August, *Typhlodromalus* spp. which were the main predators later in the season did not. Recovering from the effects of chemical pesticides, *M. tanajoa* builds up rapidly in the absence or scarcity of predators on the treated plants.

Predatory mites and *M. tanajoa* were suppressed by the pesticide applications but populations of the latter recovered and built up very rapidly before the former reinvaded the plants.

Effects of Fertilizers

Since densities of mite populations are associated with nutrient levels, studies on the mite response on 10 cassava varieties in plots treated with NPK were initiated in January 1976. The results are still inconclusive but observations during January–March indicated that mite populations were higher in all treated plots than in the untreated check plot. Within the treated plots differences apparently related to both fertilizer treatment and variety. While on variety Black Stick higher populations occurred in the P treatment, the K treatments on varieties Fromogene and Tobago Special supported the highest populations. The trends on other varieties were not consistent: initially the P treatment on variety Around-the-world supported higher populations than those of N and K, whereas populations on the N treatments on varieties Dan, DanBlue, and Butter Stick were higher than on the other treatments. However, the K treatments for these three varieties later had the highest population. Similarly, the N treated plots of Brown Stick and Maracas Black Stick and the K treated plots of Butter Stick 133-2 supported the largest numbers in January, but in February–March populations were higher in the P treated plots. For variety Red Stick the largest populations occurred in the K treated plots in January but during February–March the N treated plots carried the heaviest infestations.

Discussion and Conclusions

In Trinidad and probably in the rest of the Neotropics *M. tanajoa* for most of the year remains at very low population levels due to heavy rains. During dry periods it may reach epidemic proportions but predators play a significant role in regulating the population densities.

O. minuta is the dominant predator. It is adapted to prey on tetranychids and is known from mites from several hosts (Frank 1972). The species, being density-dependent, survives the periods of low-host density on cassava by moving on to other hosts.

Both *Typhlodromalus* spp. are in constant association with the host on cassava. They have good searching ability and are present whether the numbers of the hosts are high or low. *T. limonicus* survives the periods of host scarcity by feeding on pollen (McMurtry and Scriven 1965). Both the phytoseiid predators and *O. minuta* merit introduction against *M. tanajoa* in Africa.

Of the other predators, the staphylinids *Oligota barbadorum* and *O. centralis* and phytoseiids *Euseius hibisci* and *Phytoseuilus macropilus* need to be further evaluated.

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Susceptibility of Cassava Chips to *Araeceras fasciculatus*

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Studies were made to ascertain the relative susceptibility of cassava chips made from different varieties to *A. fasciculatus*. The test insect was collected from the storage house and cultured in the laboratory on cassava chips. Ten cassava varieties H-165, H-226, H-1687, H-2304, H-38, H-3641, H-312, H-97, H-2059, and H-1310 were used. H-226 and H-2304 were the least susceptible.

Because raw cassava tubers cannot be stored indefinitely, the common practice is to slice the tubers and sun-dry them before storing. The slices (chips) are also parboiled, dried, and stored to enhance the keeping quality. The sun-dried chips are more widely preferred for eating. Chips are attacked by more than a dozen storage pests, the most important one (*Araeceras fasciculatus*) causing great economic loss. It is commonly called the arecanut beetle as it was a specific pest of stored arecanuts (Ayyar 1940; Nair and Oommen 1969). *A. fasciculatus* eats a wide variety of foods and

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