THE POPULATION DYNAMICS OF THE CASSAVA GREEN SPIDER MITE, MONONYCHELLUS TANAJOA (BONDAR) (ACARINA: TETRANYCHIDAE) IN RELATION TO ITS PREDATORS AND ENVIRONMENTAL FACTOR IN WESTERN KENYA

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functional response curve is produced. Functional and numerical responses have been used in determining control potential of indigenous predators (Hoy et al, 1979), comparing the relative effectiveness of predators in controlling a common prey (Hoy, 1981; Parrella and Horseburgh, 1983). Therefore, it was partinent to use functional and numerical responses in determining the relative effectiveness of the four indigenous predators of M. tanajoa in the laboratory. Although there are many indigenous predators of M. tanajoa, their relative effectiveness and predatory potentials are not known. This knowledge would be useful in selecting which predators to develop and mass rear for releases against this pest.

7.2 MATERIALS AND METHODS

The following indigenous predators of M. tanajoa were used in these experiments namely, I. degenerans, N. teke (ex-Mbita and ex-Seme strains), and H. fageli. All the four predators were reared on all the stages of M. tanajoa as outlined earlier in chapter 3.

Various stages of the prey mite were used namely eggs, larvae, protonymphs, deutonymphs, females and males. Each of these stages were selected from a mixed population of all stages of M. tanajoa and placed on 2.5 cm (diameter) leaf disc. The leaf discs were excised from leaf number four

(taking leaf one as the first fully expanded leaf from the terminal shoot). When excising the leaf, care was taken to exclude the main veins. These prey stages were placed on the leaf discs at densities of 10, 20, 30, 40, 50, 60 per disc. These densities were replicated six times and the experiments were repeated four times.

The leaf discs had been placed upside down on to wet cotton wool which had been put into a perforated petri dish (9.0 cm diameter). In order to maintain the leaf disc alive the petri dishes were placed in a tray containing small quantity of water which kept the cotton wool moist. Apart from maintaining the leaf disc alive the moist cotton wool also prevented both the prey and the predators emigrating from the leaf discs especially at high prey densities.

Then specimens of mature gravid female predators which were picked from a well fed stock culture containing all the stages of the prey were starved for six hours on empty discs. One of each predator was introduced onto a monoculture of each stage of the prey. They were left for 24 hours in a humidity - temperature controlled room at mean temperature of 25 $\pm$ 1^{0}C and 65 $\pm$ 5% relative humidity. The temperature and humidity were monitored using a thermohygrograph. Illumination was maintained at 24 hours of light using flourescent tubes.

Further the data obtained on feeding rates were used in estimating the parameters for determining the searching efficiency (a') and handling time (Th). These parameters were estimated using Rogers (1972) equation:

$$N_a = N [1 - \exp (- a' \{ PT - ThNa \})]$$

where Na is the number of prey eaten by predators

P is the number of predators feeding on a particular prey stage

a' is the searching efficiency per unit time

N is the initial prey density

T is the duration of the experiment

Th is the handling time.

This equation differred from the "disc equation of Holling (1959b) in allowing for the depletion of the prey during the course of the experiment.

7.3 RESULTS

Functional response curves of the two strains, ex-Mbita and ex-Seme of N. teke, I. degenerans, adult female and fourth instar larva of H. fageli are presented in figures 7.1A to 7.5A respectively. But, the respective numerical response curves of the same are presented in figures 7.1B to 7.4B except that of fourth instar larva of H. fageli as this was an immature stage of the predator.

Functional response curves obtained for all the three phytoseiid predators, when they preyed on the juvenile stages of M. tanajoa, were type II functional response curves except the one for I. degenerans when it preyed on the protonymphs (Fig.7.3Aiii). When I. degenerans was presented with protonymph stage of the prey, it exhibited type III response curve. (Figs. 7.1Ai - iv, 7.2Ai - iv, 7.3Ai, ii, iv).

However, these phytoseiid predators exhibited type V functional response curves when they preyed on males and females as prey (Fig.7.1Av - vi, 7.2Av - vi, 7.3Av -vi) (Type V response curve was a combination of type III and I, with type I constituting a second linear rise after the plateau of type III).

Nevertheless, fourth instar larva of H. fageli exhibited type III functional response curves for all the stages of the prey (Fig. 7.5Ai -vi). Adult female H. fageli exhibited type II response curve while preying on eggs whereas type IV (dome-shaped) response curve was obtained when it preyed on larvae (Fig. 7.4Ai - ii). Type IV dome-shaped curve indicated a steep linear rise in the predators response to an increase in prey density from 10 to 30 prey/leaf disc. But, as the density of the prey continued to increase from 30 to 50 prey/disc the response of the predator decreased. The response began to increase at a decreasing rate as it approached a plateau and thereafter, the response of the predator decreased inversely with increase in prey density towards the end of the curve. But, when the same predator preyed on protonymphs, deutonymphs, females and males it displayed type V functional response curves (Fig. 7.4Aiii -vi).

Mean searching efficiency of each indigenous predator on the various prey stages is given in table 7.1. This table showed that all the predators displayed the highest searching efficiency when they preyed on males. The phytoseiid predators showed the lowest searching efficiency of less than 3.00 cm^2/hr while they preyed on larvae and females. On the other hand, both fourth instar larva and adult female H. fageli exhibited low searching efficiency when preying on larvae (2.18 $\pm$ 0.36 and 3.28 cm^2/hr

respectively) whereas they had much higher value when they preyed on females (3.49 ± 0.69 and 3.95 ± 0.59 cm^2/hr). I. degenerans had the highest searching efficiency among the phytoseiids for all the prey stages. However, adult H.fageli female had the highest searching efficiency among all the predators used in the trial. Moreover, the value of the searching efficiency of all the predators increased steadily from when they preyed on the larvae to when they preyed on males, i,e. they all had similar trend.

Relationships between the searching efficiency of the predators and the density of the various stages of M. tanajoa as prey are presented in figures 7.5 - 7.11. These figures indicated that the searching efficiency of these predators increased with prey density except that of N. teke strains whose searching efficiency decreased when the prey density was above 40/disc when they preyed on eggs and larvae. Besides, when these predators preyed on deutonymphs, their searching efficiency began to decline when the prey density was above 40/leaf disc (Fig.7.8). Moreover, the searching efficiency of the phytoseiids began to decrease when the density of female prey was 50/leaf disc. But the searching efficiency of all the predators increased with the density of male prey (Fig.7.11).

Mean handling time of each predator for the prey stages are given in table 7.2. This table showed that handling

time of each of the predators increased with age of the stages of prey from larvae to females. However, the handling times for the eggs were higher than for the larvae in all the predators. The handling time for the males as for the prey were also lower than for the females i.e. they were about two-thirds of the handling time for females in most cases.

Nevertheless N. teke ex-Mbita strain had shorter handling time for deutonymphs, females and males (0.113, 0.141 and 0.094 hours respectively) than N. teke ex-Seme strain with 0.123, 0.134 and 0.083 hours for the same prey stages respectively. On the other hand, N. teke ex-Seme strain had shorter handling time for eggs (0.092 hours), larvae (0.075 hours) and protonymphs (10.089 hours) than N. teke ex-Mbita with 0.093, 0.082 and 0.098 hours for the same prey stages respectively.

Among the phytoseiids, I. degenerans had the longest handling time for all the prey stages compared to the N. teke strains. Adult female H. fageli had the shortest handling time for all the prey stages compared with its fourth instar larva. Moreover, the adult female H. fageli had the shortest handling time for all the prey stages compared with all the predators used in this trial.

Percentage prey consumption of the predators per prey density are presented in figures 7.12 to 7.16. These figures indicated that the phytoseiid predators, N. teke strains and I. degenerans consumed significantly higher percentage of prey at low prey densities (10 to 20 prey/ disc) than they did at high prey densities ($F = 5.36$, DMRT, $df = 5,20$, $P < 0.01$, Figures 7.12 - 7.14i - vi). On the other hand, both fourth instar larva and adult female H. fageli consumed significantly higher percentage of prey at high prey densities (40 - 60 prey/disc) than they did at low prey densities (DMRT, $df = 20$, $P < 0.01$, Figures 7.15 - 7.16i - vi).

Mean hatchability (percent) of each predators' eggs laid during the assessment of their functional responses per density is given in table 7.3. This table showed that when they preyed low density larvae,lower percentage of their laid eggs at that time hatched than they did when these predators preyed on high density larvae ($F = 7.21$, $df = 5,99$, and DMRT, $df = 99$, $P < 0.05$). But, there were no significant differences in the percentage egg hatchability of the eggs laid when the predators preyed on any density of the other stages (DMRT, $df = 99$, $P < 0.05$).

Mean predators' egg hatchability percent per prey stage consumed by the female predators is given in table 7.4 This table showed that there were significant differences in

number of predators and eggs hatched (percent) among the eggs which each predator laid when it was feeding on a particular prey stage (DMRT, df = 99, $P < 0.05$). Among the eggs laid by N teke ex-Mbita strain, those laid when it was feeding on eggs, deutonymphs and females had significantly higher egg hatchability, 97.58, 94.48 and 96.58% respectively than those laid when it fed on larvae, protonymphs and males 60.67, 68.00 and 56.16% respectively ($F = 4.67$, df = 5,69, $P < 0.01$ and DMRT, df = 69). Similarly, eggs laid by N. teke ex-Seme and I. degenerans when they were preying on eggs, deutonymphs and females had significantly higher egg hatchability than those laid when they were feeding on larvae, and protonymphs (DMRT, df =69, $P < 0.05$).

Moreover, eggs laid by H. fageli when it was preying on eggs, deutonymphs and females had significantly higher egg hatchability of 80.98, 78.47 and 77.19% respectively than those laid when it was feeding on larvae, protonymphs and males (56.84, 56.19 and 47.65% respectively), (DMRT, df = 69, $P < 0.05$, Table 7.4). The lowest egg hatchability (56.16, 51.00, 57.75 and 47.65%) were obtained when the predators preyed on the males as prey.

7.4 Discussion

Results of this experiment indicated that the functional and numerical responses of these indigenous predators of M. tanajoa were similar to those curves proposed by Holling (1959a,b 1965) and Sabelis (1985). The functional response curves type II which were obtained when the phytoseiid predators, N. teke ex-Mbita and ex-Seme strains and I. degenerans preyed on the juvenile stages of M. tanajoa indicated that these predators responded to increases in prey density very sharply at low prey densities. But as the prey density became high (more than 40/disc) their response decreased indicating that they had a maximum threshold above which increase in prey density did not increase their prey consumption and their searching efficiency declined.

The fact that these predators consumed higher number of prey (percent) at low prey density than they did at high prey densities revealed that they are probably, more efficient at low prey density than at high prey densities. Fernando and Hassell (1980) found that Phytoseiulus persimilis Athias-Henriot preyed more on T. urticae at low prey density then it did at high prey densities. Takafuji and Chant (1976) demonstrated that P. persimilis and I. degenerans preying on Tetranychus pacificus McGregor had a

maximum prey density above which the predator did not increase its rate of prey consumption.

However, type V functional response curve obtained when these same phytoseiid predators preyed on males and females of M. tanajoa indicated that, potentially the responses of these predators could increase with the prey densities except for some factors such as interference. Mori and Chant (1966) had similar occurrence and attributed this interferrence to increased physical contact by P. persimilis with its prey T. urticae. This disturbance reduced the predators success in capturing prey. But as the prey density was reduced by predators feeding, this interferrence was concurrently minimised and the predators increased their killing rates. Therefore, Chant (1961) Mori and Chant (1966), Kuchlein (1967) and Mori (1969) have concluded that high prey densities disturb the phytoseiid predators and thus cause a decrease in the functional and/or numerical responses of the predators. Laing and Osborn (1974) claimed that the interferrence with the predator was partly due to the predators confusion, and more importantly, the confusion led to the abandonment of kills. In this study the phytoseiid predators moved very fast and then rested in the crevisees on the substrate.

Besides, Croft and Blyth (1979) urgued that this plateauing of the functional response curves at high prey

densities was an indication of the satiation level of the particular predator. Further they elaborated that the satiation level increased with temperature i.e. within the range of 12 to 30^{0}C the predation rate increased almost linearly with temperature. Probably, the predators required to consume more males in order to reach their satiation level. Moreover, it is suggested that the phytoseiids consumed more female prey because these predators, being physiologically sexually mature and ovipositing females, they had some physiological requirements which female prey fulfilled. This suggestion is supported by the high numerical response and percentage egg viability obtained when the phytoseiids preyed on female M. tanajoa. Generally, when female predators are undergoing their oviposition periods, their food demand increases as a result of the high food turn-over due to the exra feeding by the developing embryo in them. Holling (1959a, b) and Santos (1975) reported similar findings with ovipositing females of different species of predators.

However, the fourth instar larva of H. fageli, having type III functional response curves for all the prey stages revealed firstly, that this predator does not change its feeding habit in response to the particular prey stage. Secondly, the plateauing of the curve indicated that this instar had an upper or maximum density above which its predation rate does not increase. Besides, this larva

pupated during the fourth day of the experiment especially at high prey densities. Probably, the larva grew much faster at high prey densities than it did at low prey densities. Probably, this happened because its food was readily available in sufficient quantities which satisfied its physiological requirements for fast development and pupation. Moreover, the fourth instar larva did not have the ability to detect prey except by direct contact. This was so presumably, because the larval stage had not yet developed its sensory system for such perception. This behavioural phenomenon may account for the sigmoid curve obtained for this stage of H. fageli with all the six stages of the prey.

Nevertheless, adult female H. fageli had type II and IV functional response curves when it preyed on eggs and larvae respectively. Although type II response could be due to the same reasons as those affecting the phytoseiids, type IV functional response curve was a dome-shaped curve in which the response of the predators' predation rate decreased inversely with increases in prey density particularly at high prey densities. The decline in predation rate was probably, because the larvae might not have been as palatable as the other prey stages. Subsequently, the larval stage did not stimulate further predation beyond a certain threshold level or it was not a preferred prey.

However, female H. fageli showed type V functional response curve when it preyed on protonymphs, deutonymphs, females and males which suggested that this predator's predation rate was increasing with the prey densities when the trial was terminated. These results were confirmed by the fact that it consumed more prey at high prey densities. These results revealed that H.fageli was probably, more effective at high prey densities than at low prey densities. McMurty (1977) concluded that staphylinids and coccinelids were effective at high prey densities because they were voracious feeders which required high mite densities for their development and reproduction.

Searching efficiency of the phytoseiids except that of I. degenerans were lower than those of the adult female H. fageli. Probably, H. fageli was more mobile than the phytoseiids bacause it was an adult beetle with more advanced locomotory ability. Besides, the phytoseiids stopped feeding and rested shortly before and after each oviposition. Awan (1974) also observed cessation of feeding in P. persimilis for a short period before and after ovipositing an egg. Thus, the pattern of activities affected the searching efficiency.

Moreover, I. degenerans had the highest searching efficiency among the phytoseiids, compared with those of N. teke strains. Probably, this difference arose because I.

degenerans was the most restless predator of all the three phytoseiids, especially at high prey densities. This species was more restless at high prey density because it was constantly disturbed by the prey bumping on it. Eveleigh and Chant (1982 c) also had observed that I. degenerans became more restless as the prey density increased whereas P. persimilis was not.

Besides, it was observed in the field that during the high density of mites, I. degenerans migrated to leaves lower down the plant where there were few mites and it laid its eggs on over-exploited leaves and depressions on those leaves.

The mean handling time of the predators increased with the size of the prey stage i.e. handling time for larvae was the shortest while that of the female was the longest. Handling time of each predator for the egg was longer than it was for the larvae although larvae were bigger than the eggs. Therefore, it was more difficult to handle the eggs than the larvae for the predators. Fernando and Hassell (1980) had similar results with P. persimilis on T. urticae.

However, among the predators used, adult female H. fageli had the shortest handling time compared with the others. Possibly, this predator took the shortest period to capture and consume its prey because it was a bigger

predator than the others. Moreover, I. degenerans was less aggressive than N. teke strains. Hassell and May (1974) suggested that aggressive behaviour of a predator can influence its search rate and handling time. It is also suggested that interference by the prey at high prey densities could reduce the handling time of the phytoseiid predators. This interference of the predator by the prey at high prey densities often resulted in the abandonment of prey (Santos 1975; Laing and Osborn 1974).

Although, the numerical response curves revealed that the number of eggs laid by the phytoseiid predators increased with prey densities, the curves indicated that the predators had upper physiological limit above which egg output did not increase with prey densities. Furthermore, the evidence presented by other authors suggested that for P. persimilis (Dosse, 1958; Laing, 1968; McClanahan, 1968) and I.degenerans (Takafuji and Chant, 1976) mean total eggs per female was constant. Friese and Gilstrap (1982) found that for Amblyseius californicus , Metaseiulus occidentalis (Nesbitt) and P. persimilis there was a fixed potential fecundity, and that within those potentials, as the ovipositional rate increased, the ovipositional period decreased. Moreover, Sabelis (1981) using model estimation of biomass conversion suggested that 60 - 70% of the prey ingested was utilized in predator egg production.

However, in this study significantly higher numerical responses were obtained when these phytoseiid predators preyed on eggs, deutonymphs and females than when they preyed on larvae, protonymphs and males. Blommers (1976) had high numerical responses when Amblyseius bibens Blommers preyed on female Tetranychus neocaledonicus Andre' than when it preyed on the juveniles of this prey. Therefore, it is postulated that eggs, deutonymphs and females were nutritionally suitable for egg formation, development and maturation.

The numerical responses of H. fageli were also predominantly type III as those of the phytoseiid predators. Nevertheless, the egg hatchability of H. fageli was low compared to those of the phytoseiids. This could have been due to their long incubation period during which they were handled frequently as they were being changed from deteriorating substrate to another fresh leaf discs. But this numerical response indicated that H. fageli could reproduce when it fed on M.tanajoa as prey and that it was capable of sustaining its subsequent generations even in the wild. However, eggs laid when this predator was feeding on low prey density had low egg hatchability which indicated that these eggs had poor formation, development and maturation. Hence, it was observed that H. fageli had poor egg viability at low prey density.

Therefore, it can be concluded that the phytoseiid predators can be used to maintain this pest at low density because they are more efficient at low prey densities as they feed on high percentage of prey at low densities and reproduce sufficiently viable eggs with high percentage hatchability. On the other hand, both larval stage and adult female H. fageli were voracious feeders which consumed high percentage of prey at high prey densitites although its percentage egg hatchability was lower than those of the phytoseiid predators.

Fig. 7.1

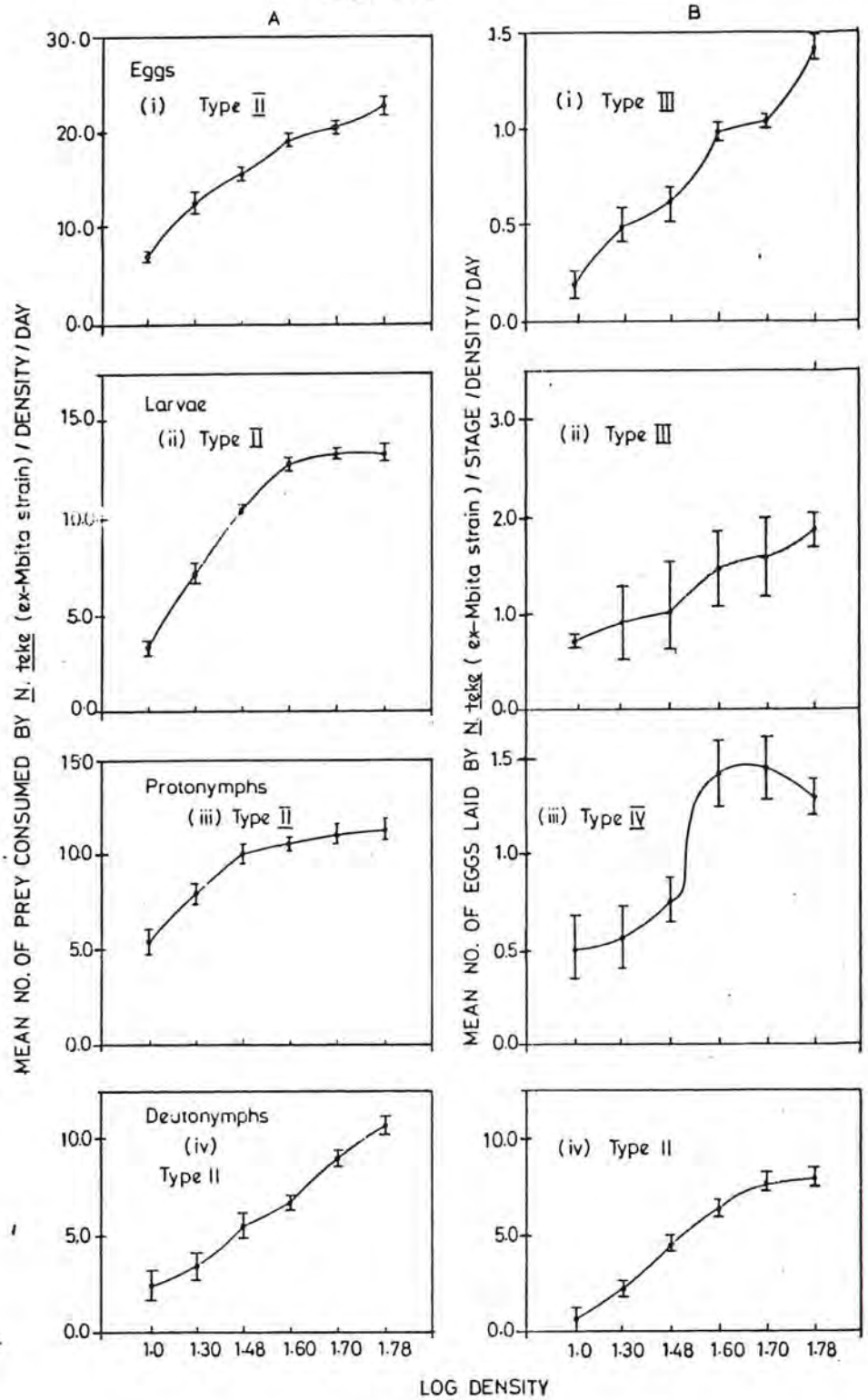

A
B
Eggs
(i) Type II
Larvae
(ii) Type II
Protonymphs
(iii) Type II
Deutonymphs
(iv)
Type II
(i) Type III
(ii) Type III
(iii) Type IV
(iv) Type II
MEAN NO. OF PREY CONSUMED BY N. teke (ex-Mbita strain) / DENSITY / DAY
MEAN NO. OF EGGS LAID BY N. teke (ex-Mbita strain) / STAGE /DENSITY / DAY
LOG DENSITY
1.0 1.30 1.48 1.60 1.70 1.78

Figure 7.3 Functional and numerical responses of *I. degenerans* on various stages of *M. tanajoa* as prey at various densities.

Figure 7.2 Functional and numerical responses of N. teke ex-Seme strain on various stages of M. tanajoa as prey at various densities continued.

Figure 7.2 Functional and numerical responses of N. teke ex-Seme strain on various stages of M. tanajoa as prey at various densities.

Figure 7.1 Functional and numerical responses of N. teke ex-Mbita strain on various stages of M. tanajoa as prey at various densities continued.

Fig. 7.3

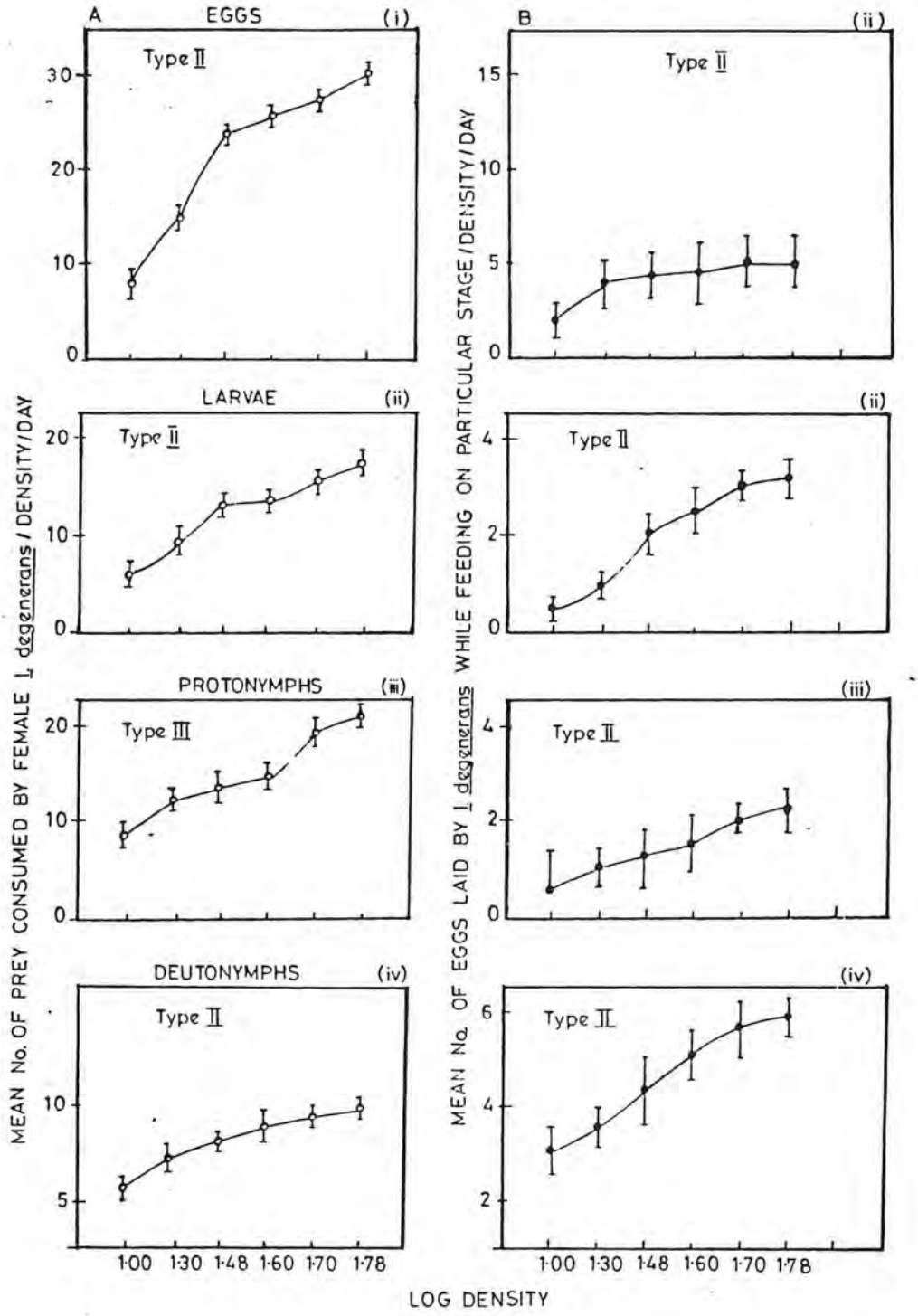

A
EGGS
(i)
Type II
30
20
10
0
B
(ii)
Type II
15
10
5
0
LARVAE
(ii)
Type II
20
10
0
(ii)
Type II
4
2
0
PROTONYMPHS
(iii)
Type III
20
10
0
(iii)
Type II
4
2
0
DEUTONYMPHS
(iv)
Type II
10
5
(iv)
Type II
6
4
2
1·00 1·30 1·48 1·60 1·70 1·78
1·00 1·30 1·48 1·60 1·70 1·78
MEAN No. OF PREY CONSUMED BY FEMALE L. degenerans / DENSITY/DAY
MEAN No. OF EGGS LAID BY L. degenerans WHILE FEEDING ON PARTICULAR STAGE/DENSITY/DAY
LOG DENSITY

Fig. 7.3 contd.

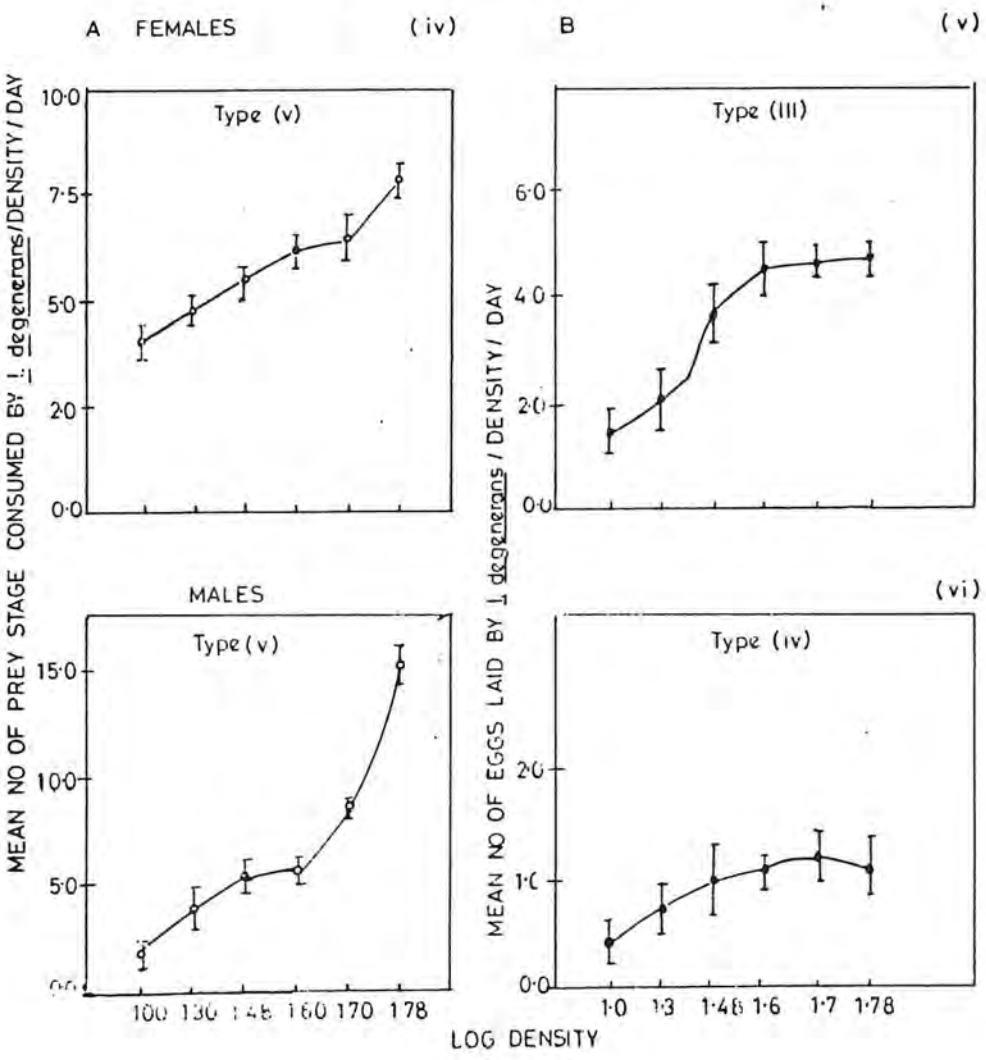
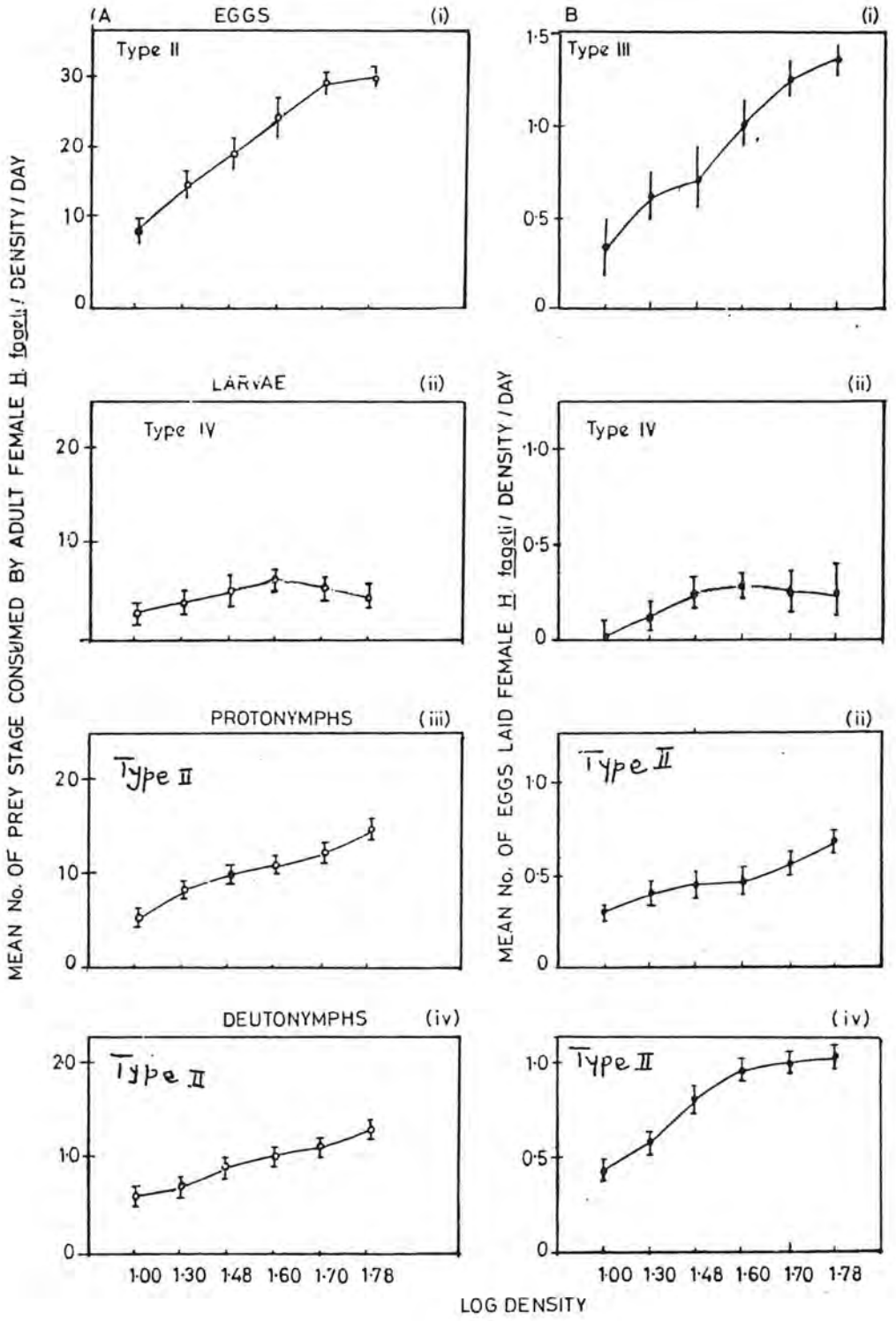

A FEMALES
(iv)
B
(v)
Type (v)
Type (III)
MEAN NO OF PREY STAGE CONSUMED BY 1 degenerans/DENSITY/DAY
MEAN NO OF EGGS LAID BY 1 degenerans / DENSITY / DAY
10·0
7·5
5·0
2·0
0·0
6·0
4·0
2·0
MALES
(vi)
Type (v)
Type (iv)
15·0
10·0
5·0
1·0
1·3
1·48
1·6
1·7
1·78
LOG DENSITY

Fig. 7.4


A
EGGS
(i)
Type II
30
20
10
0
B
(i)
Type III
1·5
1·0
0·5
0
LARVAE
(ii)
Type IV
20
10
(ii)
Type IV
1·0
0·5
0
PROTONYMPHS
(iii)
Type II
20
10
0
(ii)
Type II
1·0
0·5
0
DEUTONYMPHS
(iv)
Type II
20
1·0
0
(iv)
Type II
1·0
0·5
0
1·00 1·30 1·48 1·60 1·70 1·78
LOG DENSITY
MEAN No. OF PREY STAGE CONSUMED BY ADULT FEMALE H. taggli / DENSITY / DAY
MEAN No. OF EGGS LAID FEMALE H. taggli / DENSITY / DAY

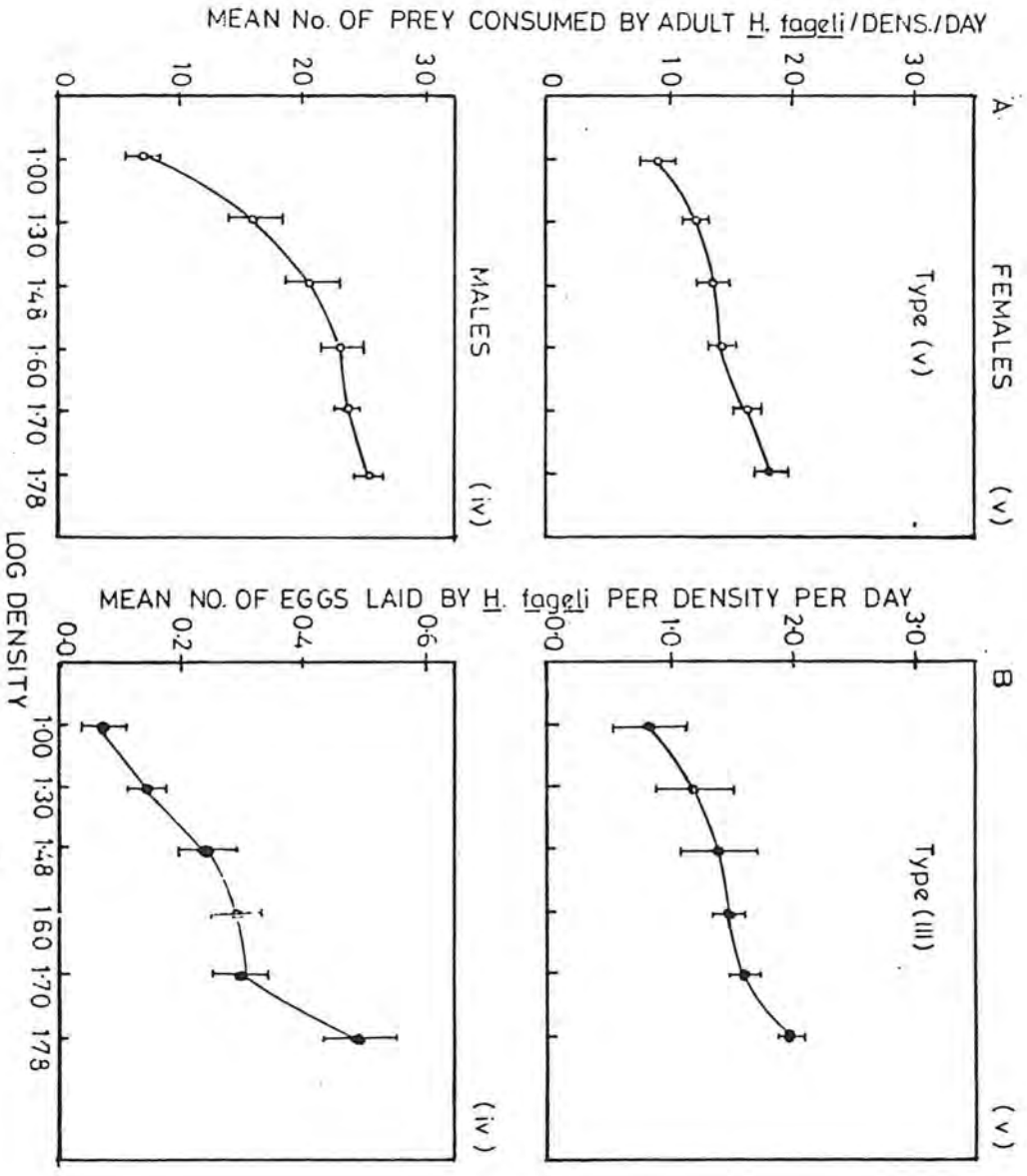
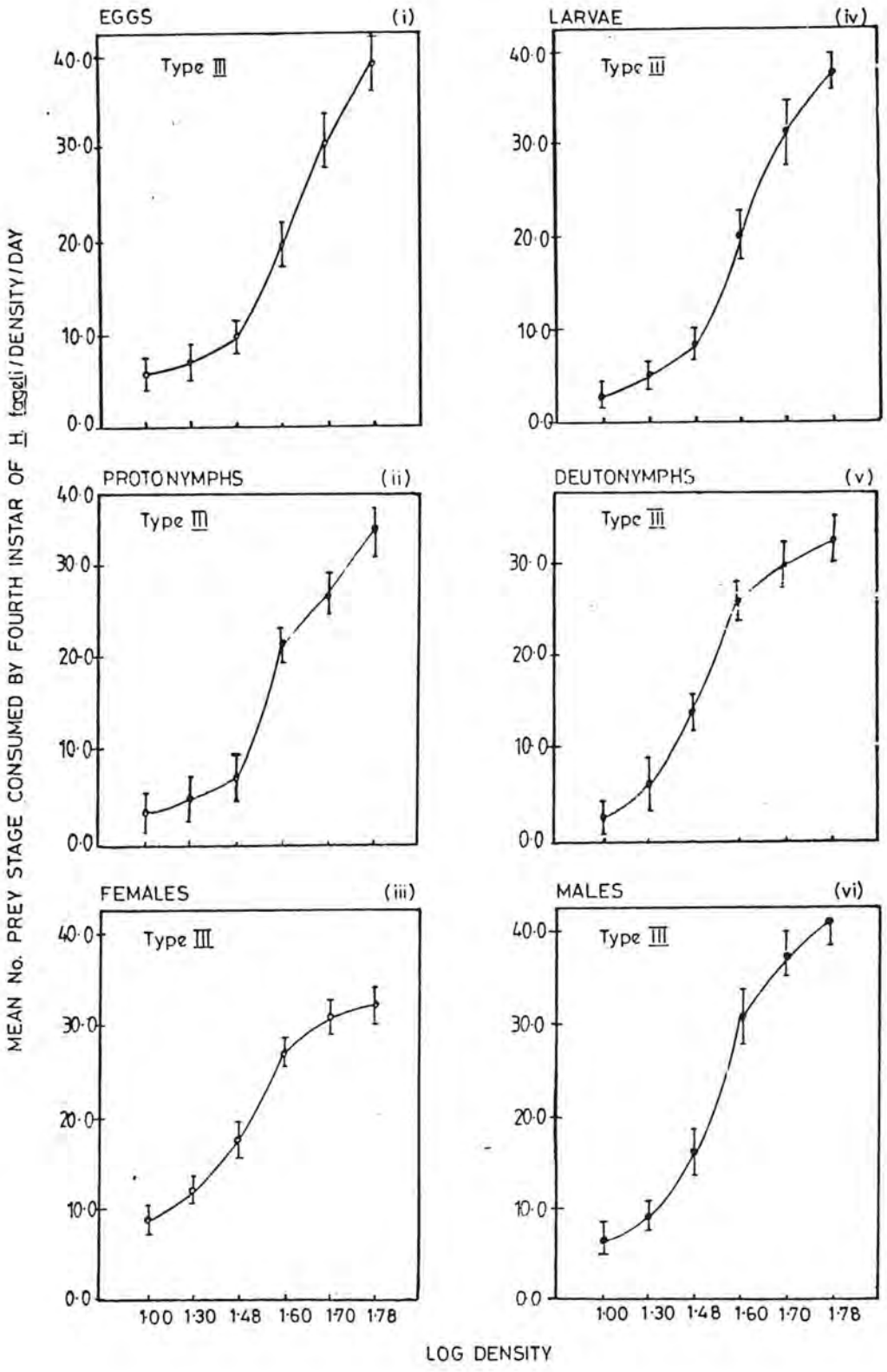

MEAN No. OF PREY CONSUMED BY ADULT H. fageli / DENS. / DAY
A
FEMALES (v)
Type (v)
MALES (iv)
MEAN NO. OF EGGS LAID BY H. fageli PER DENSITY PER DAY
B
Type (III)
(v)
(iv)
0 10 20 30
0·0 1·0 2·0 3·0
0·0 0·2 0·4 0·6
1:00 1:30 1:48 1:60 1:70 1:78
LOG DENSITY

Fig. 7.4 contd.

Fig. 7.5


EGGS
(i)
Type III
LARVAE
(iv)
Type III
PROTONYMPHS
(ii)
Type III
DEUTONYMPHS
(v)
Type III
FEMALES
(iii)
Type III
MALES
(vi)
Type III
40·0
30·0
20·0
10·0
0·0
1·00 1·30 1·48 1·60 1·70 1·78
MEAN No. PREY STAGE CONSUMED BY FOURTH INSTAR OF H. fagali / DENSITY / DAY
LOG DENSITY

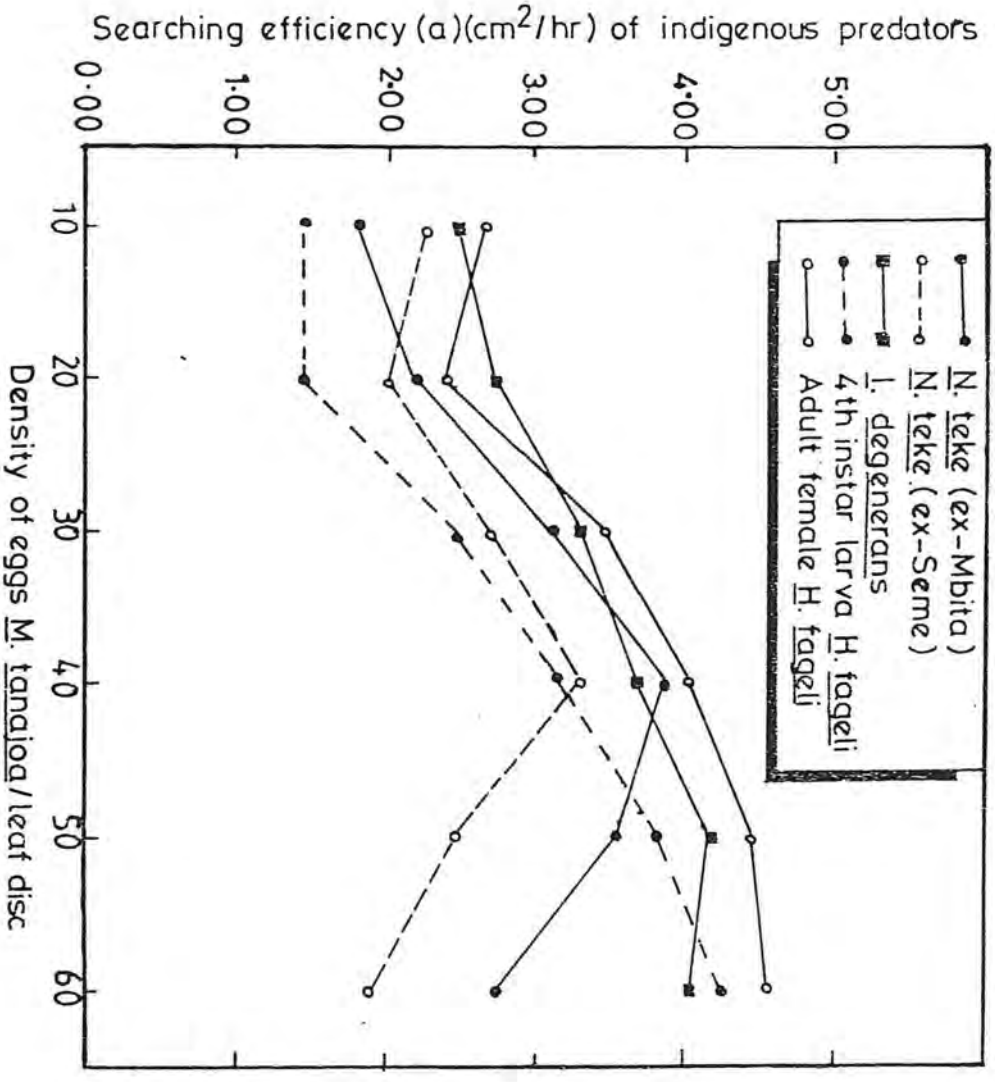

Searching efficiency (a)(cm²/hr) of indigenous predators
0·00
1·00
2·00
3·00
4·00
5·00
10
20
30
40
50
60
Density of eggs M. tanajoa/leaf disc
N. teke (ex-Mbita)
N. teke (ex-Seme)
I. degenerans
4th instar larva H. fageli
Adult female H. fageli

Fig. 7.6

Fig. 7.7

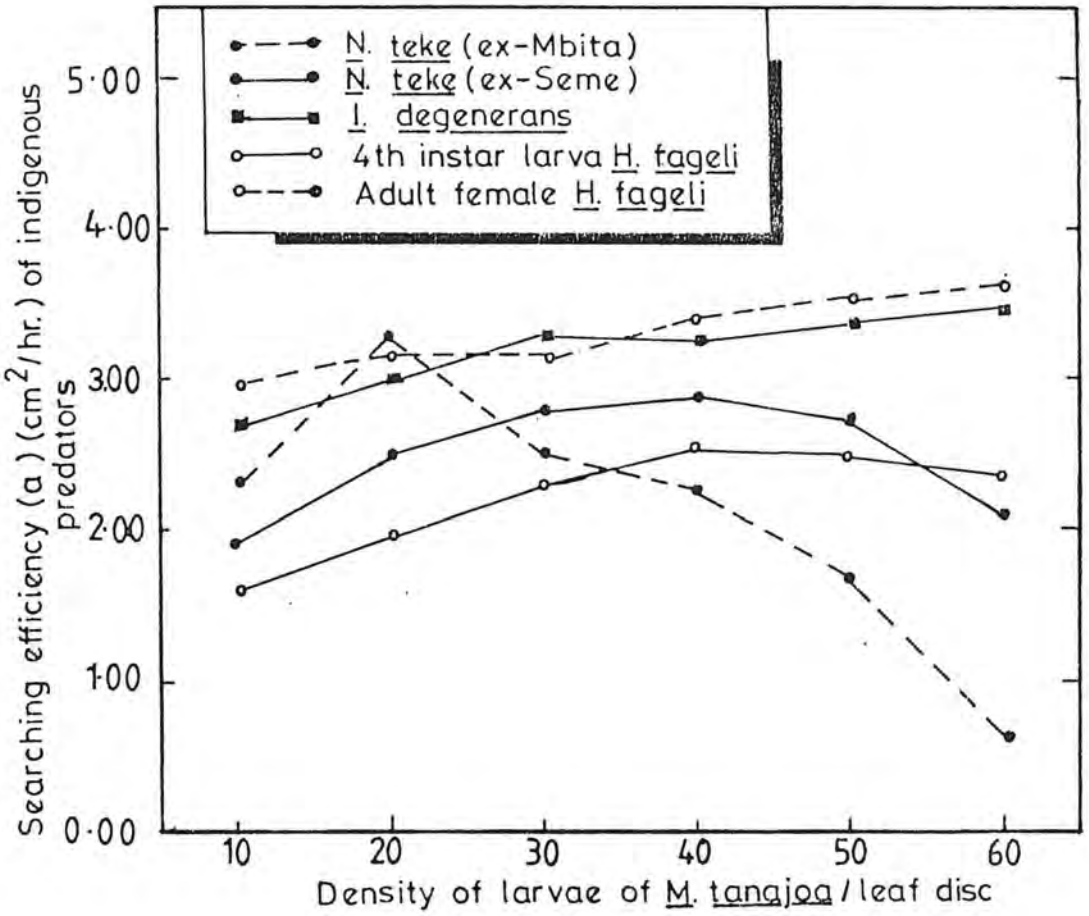

N. teke (ex-Mbita)
N. teke (ex-Seme)
I. degenerans
4th instar larva H. fageli
Adult female H. fageli
Searching efficiency (a) (cm²/hr.) of indigenous predators
5·00
4·00
3·00
2·00
1·00
0·00
10
20
30
40
50
60
Density of larvae of M. tanajoa / leaf disc

Fig. 7.8

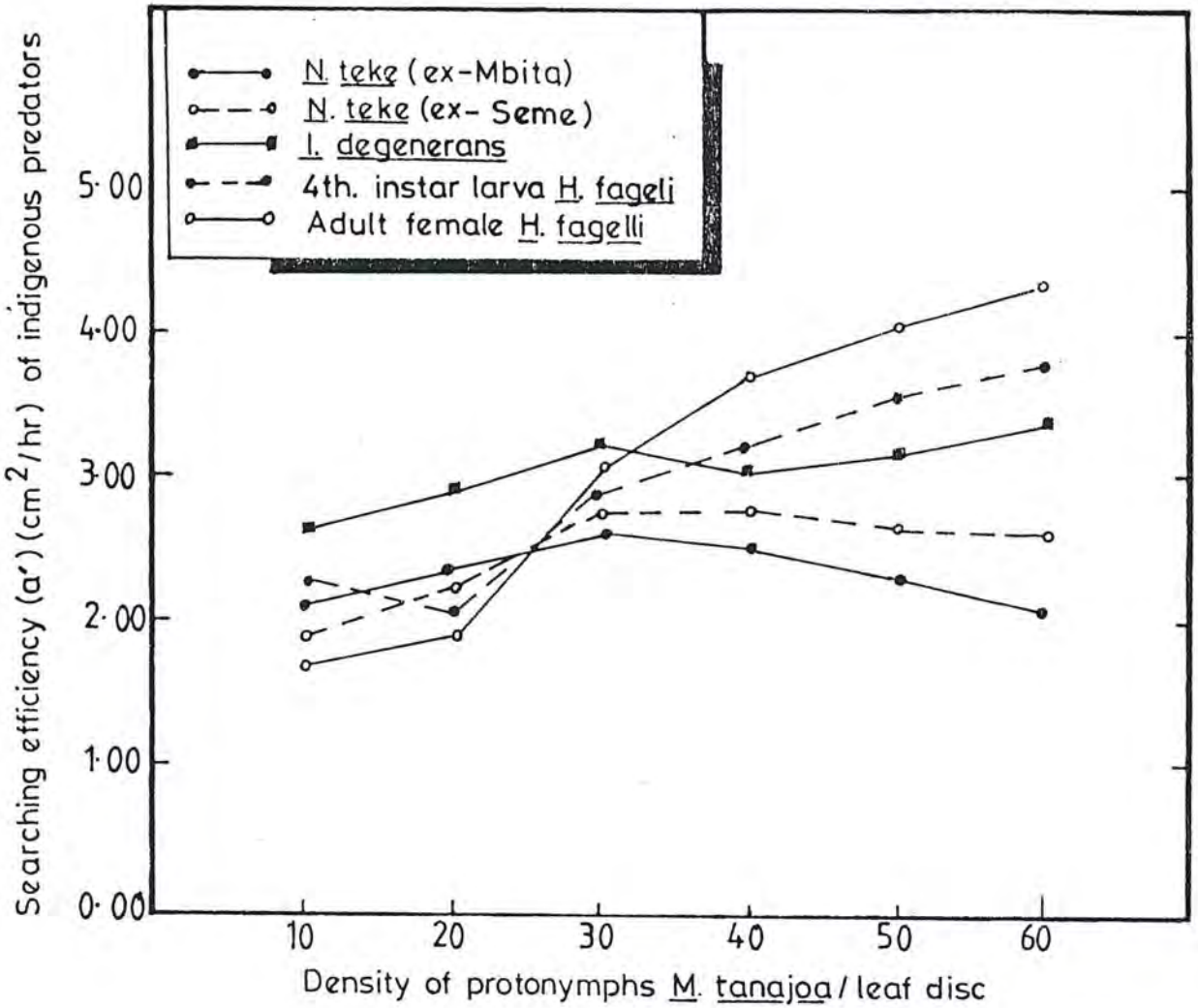

N. teke (ex-Mbita)
N. teke (ex- Seme)
I. degenerans
4th. instar larva H. fageli
Adult female H. fagelli
Searching efficiency (a') (cm²/hr) of indigenous predators
5·00
4·00
3·00
2·00
1·00
0·00
10
20
30
40
50
60
Density of protonymphs M. tanajoa / leaf disc

Fig. 7.9

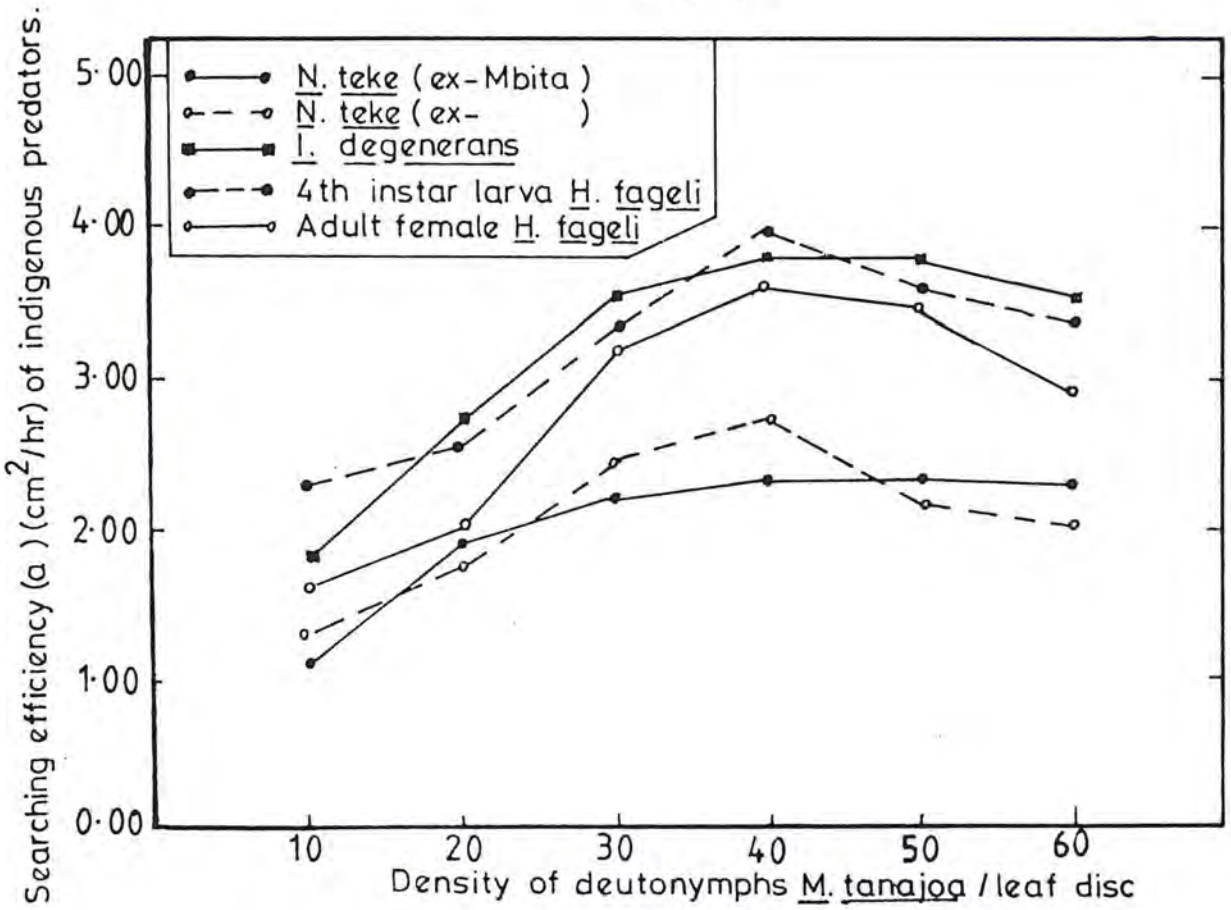

N. teke (ex-Mbita)
N. teke (ex-)
I. degenerans
4th instar larva H. fageli
Adult female H. fageli
Searching efficiency (a) (cm²/hr) of indigenous predators.
5·00
4·00
3·00
2·00
1·00
0·00
10
20
30
40
50
60
Density of deutonymphs M. tanajoa / leaf disc

Fig. 7.10

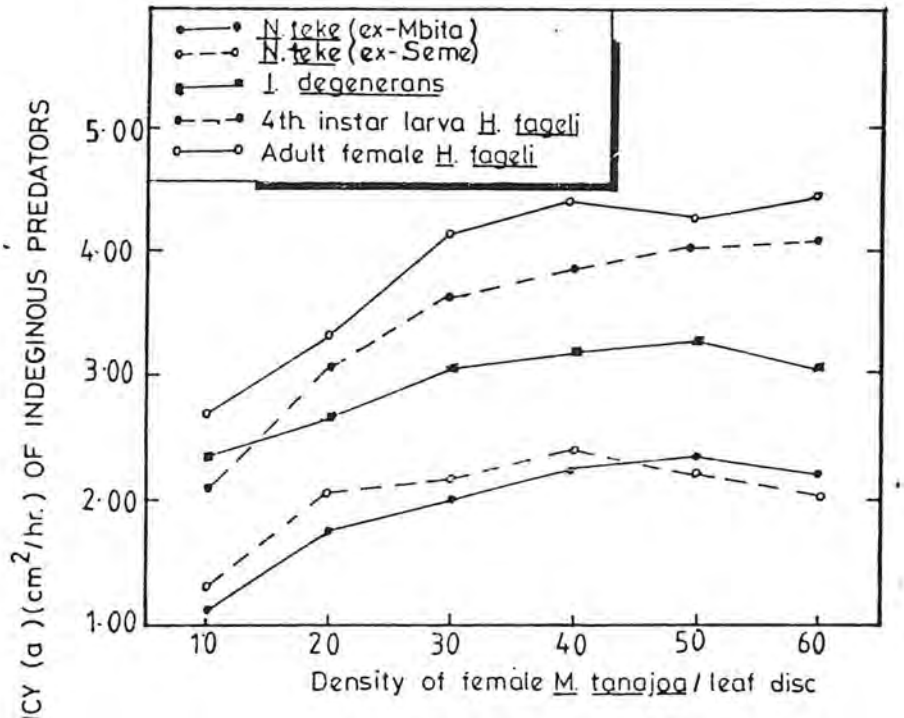


Fig. 7.11

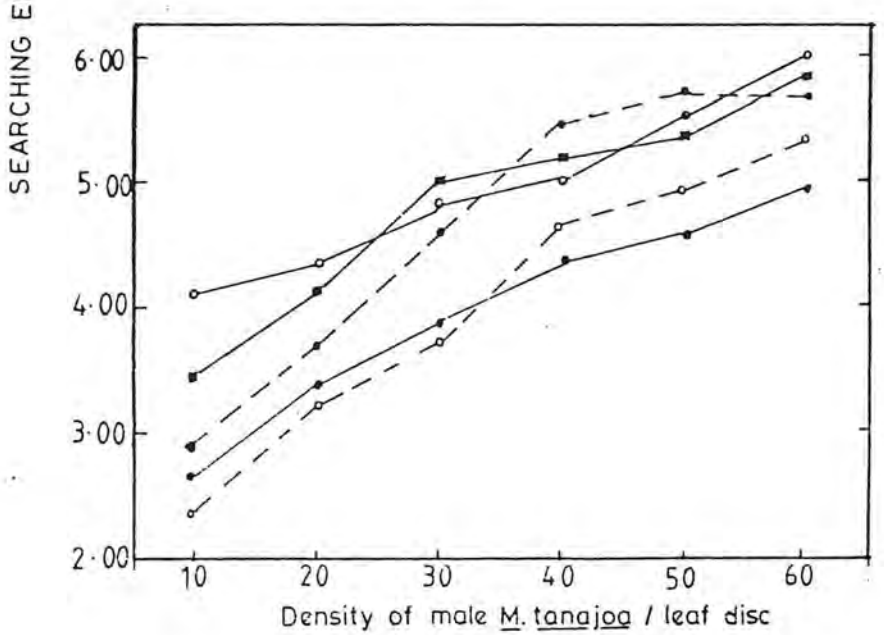


Fig. 7.12

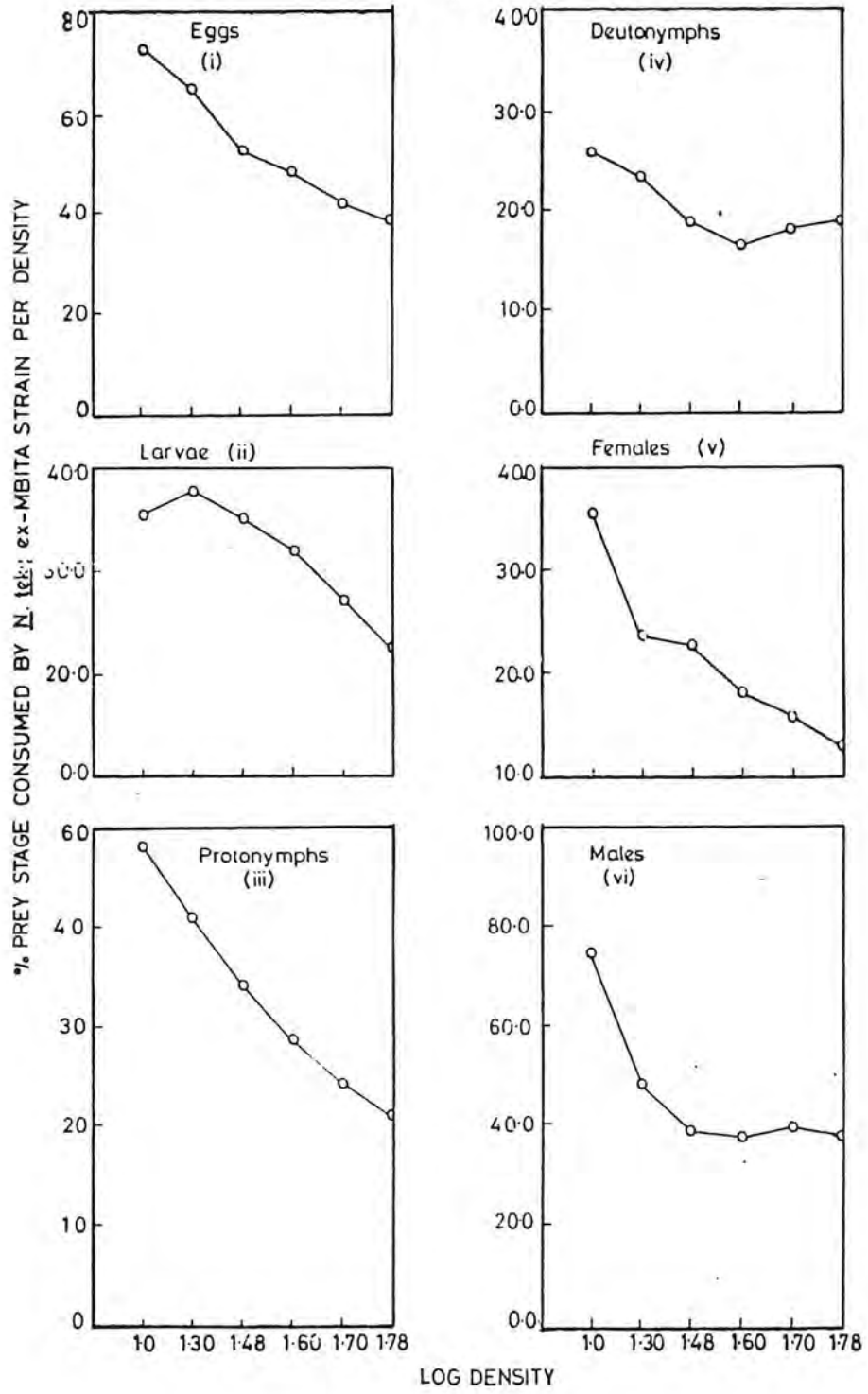

Eggs (i)
Deutonymphs (iv)
Larvae (ii)
Females (v)
Protonymphs (iii)
Males (vi)
% PREY STAGE CONSUMED BY N. tel; ex-MBITA STRAIN PER DENSITY
LOG DENSITY
1·0 1·30 1·48 1·60 1·70 1·78

Fig. 7.13

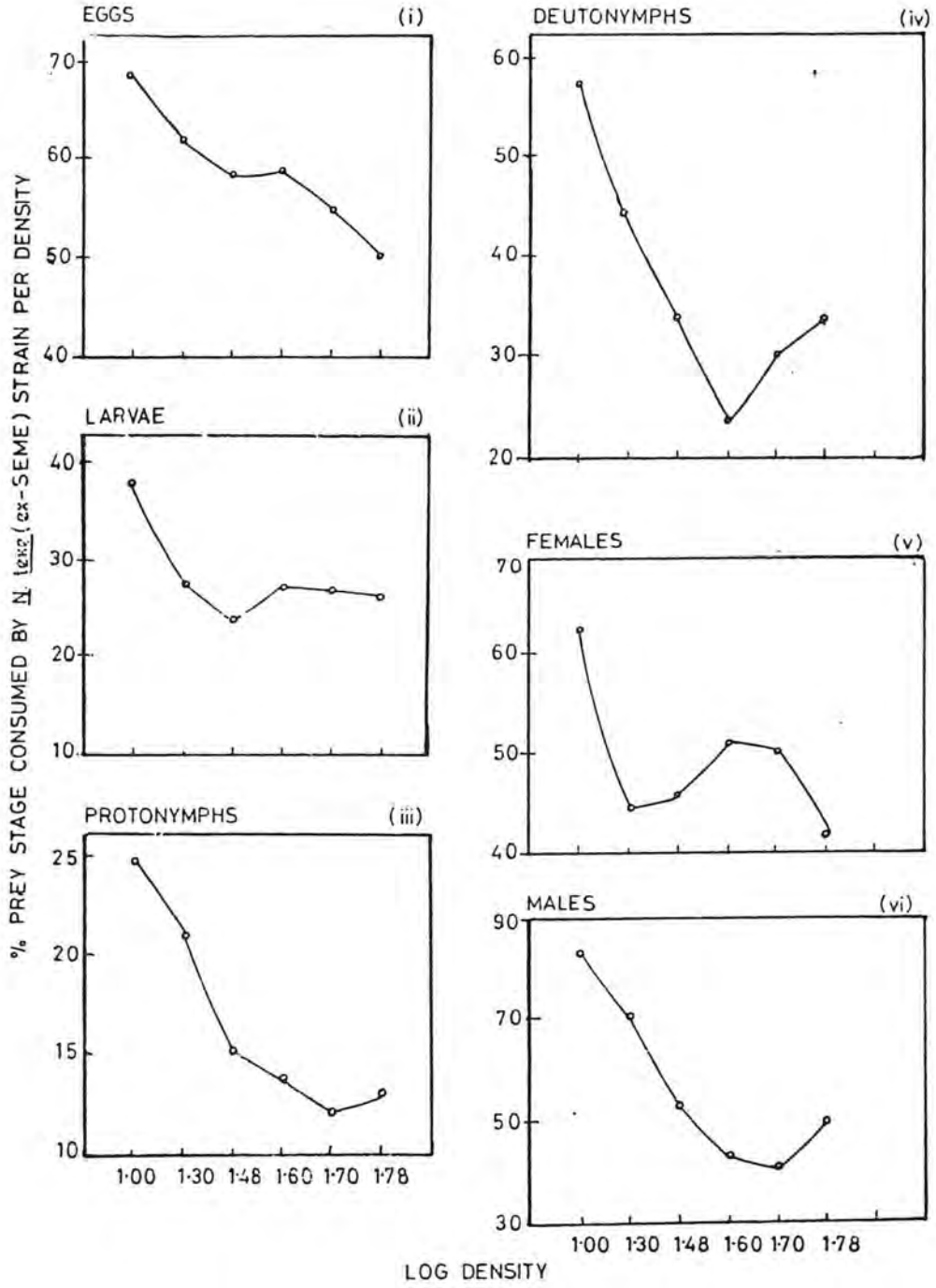

EGGS
(i)
LARVAE
(ii)
PROTONYMPHS
(iii)
DEUTONYMPHS
(iv)
FEMALES
(v)
MALES
(vi)
% PREY STAGE CONSUMED BY N. tegus (ex-SEME) STRAIN PER DENSITY
1·00 1·30 1·48 1·60 1·70 1·78
LOG DENSITY

Fig. 7.14

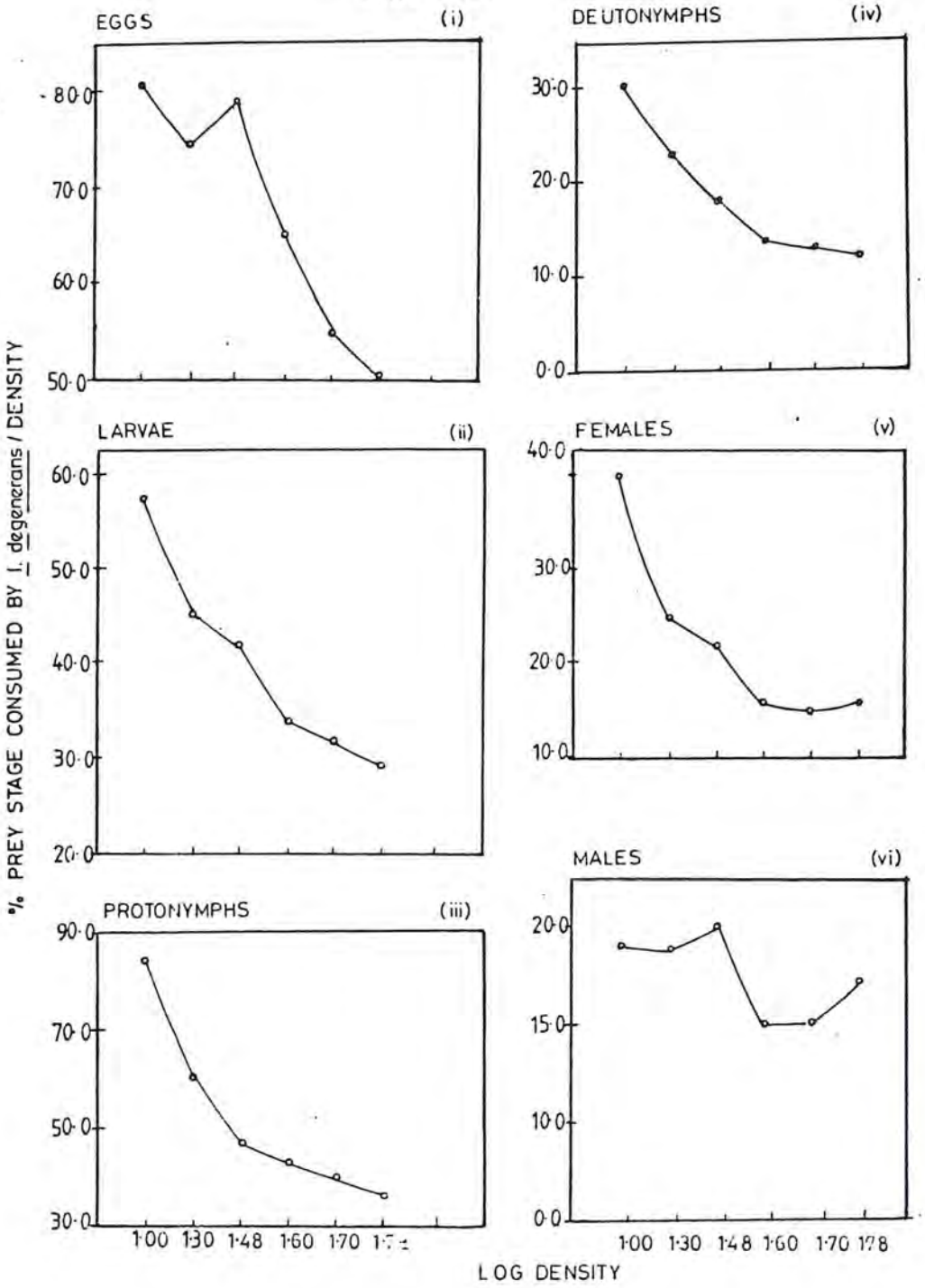
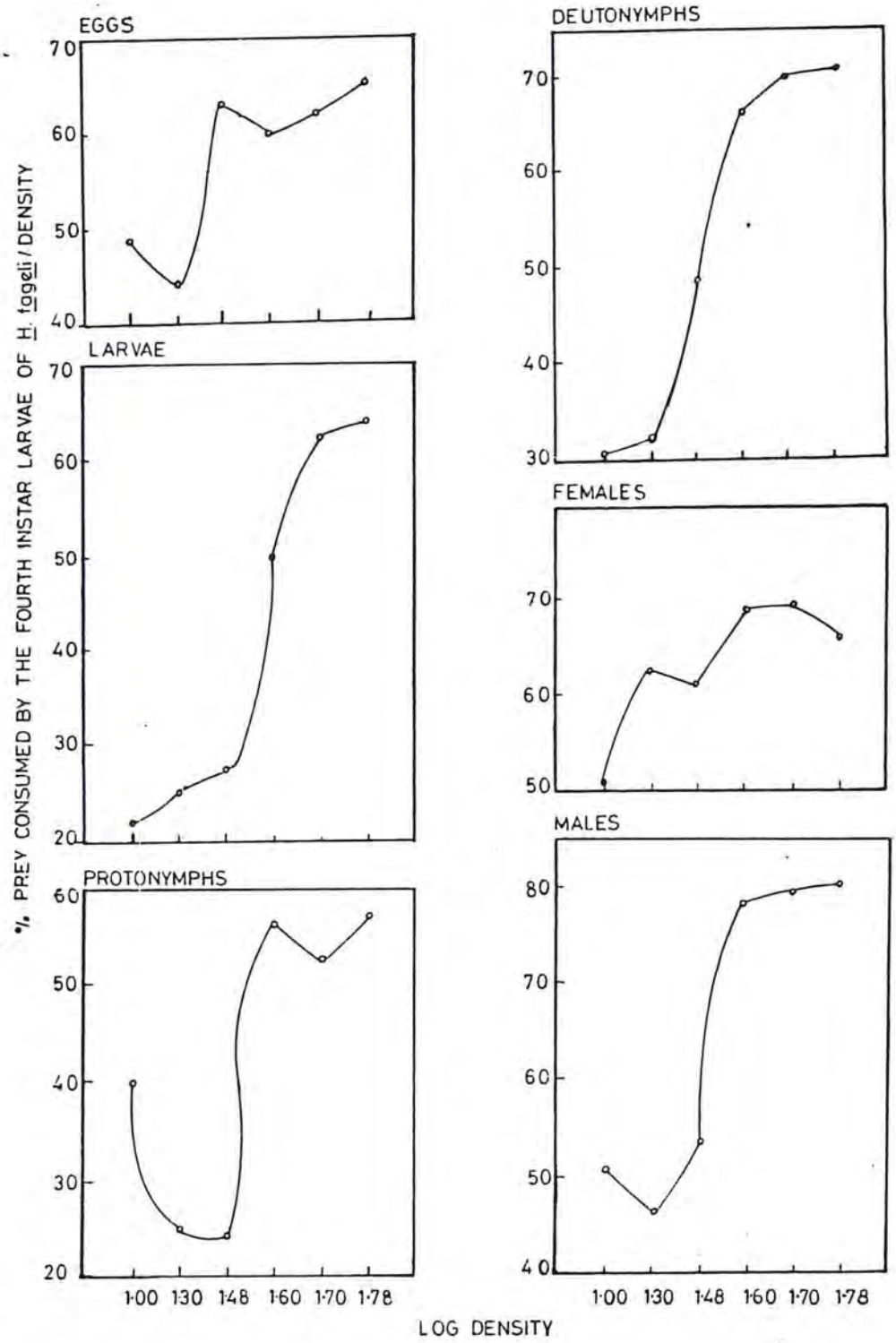

EGGS
(i)
80·0
70·0
60·0
50·0
DEUTONYMPHS
(iv)
30·0
20·0
10·0
0·0
LARVAE
(ii)
60·0
50·0
40·0
30·0
20·0
FEMALES
(v)
40·0
30·0
20·0
10·0
PROTONYMPHS
(iii)
90·0
70·0
50·0
30·0
MALES
(vi)
20·0
15·0
10·0
0·0
1·00 1·30 1·48 1·60 1·70 1·78
% PREY STAGE CONSUMED BY I. degenerans / DENSITY
LOG DENSITY

Fig. 7.15


EGGS
LARVAE
PROTONYMPHS
DEUTONYMPHS
FEMALES
MALES
% PREY CONSUMED BY THE FOURTH INSTAR LARVAE OF H. toggli / DENSITY
LOG DENSITY
1·00 1·30 1·48 1·60 1·70 1·78

7.16

Fig. 7.16

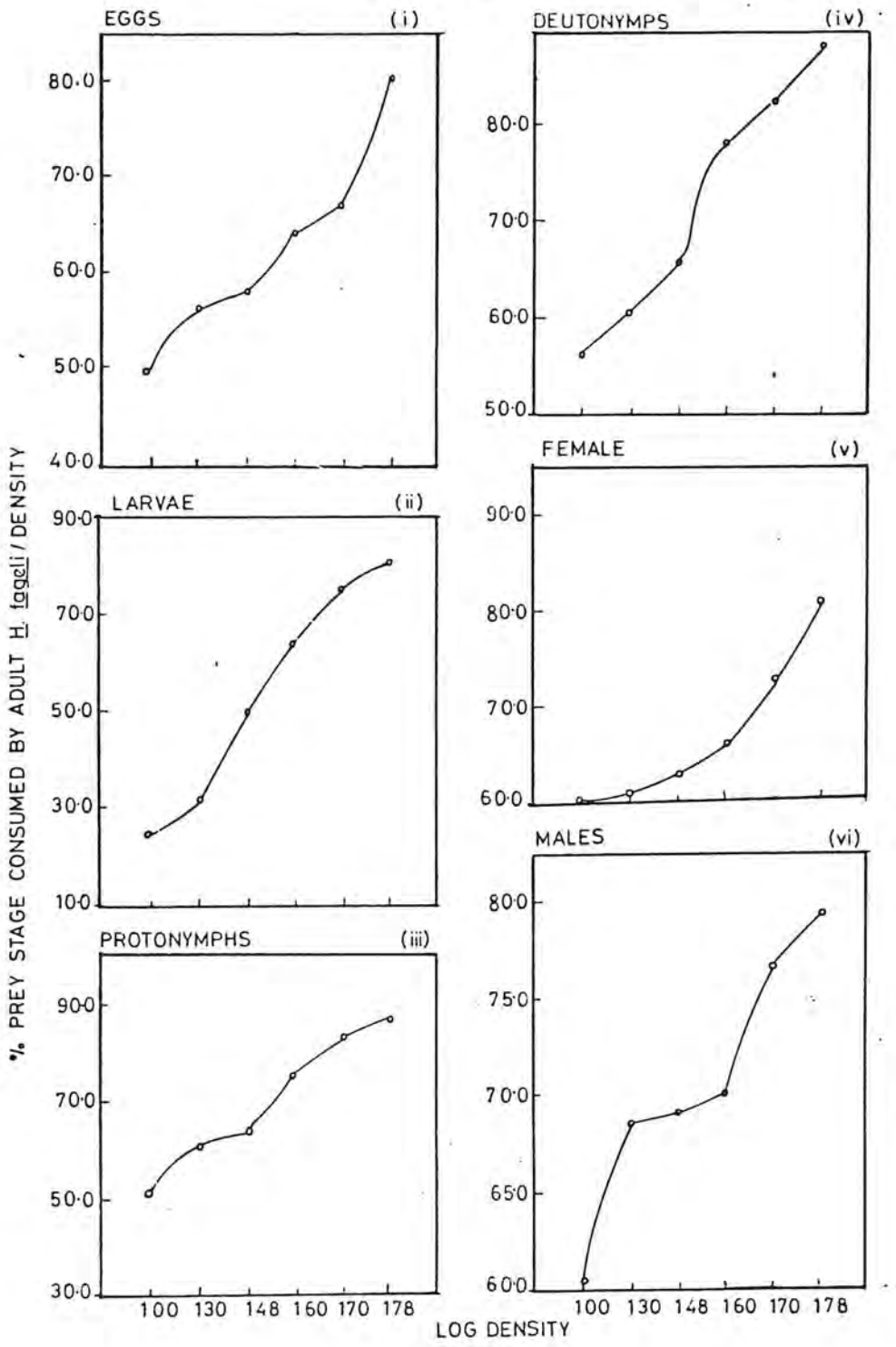

EGGS (i)
LARVAE (ii)
PROTONYMPHS (iii)
DEUTONYMPS (iv)
FEMALE (v)
MALES (vi)
% PREY STAGE CONSUMED BY ADULT H. foggli / DENSITY
LOG DENSITY
100 130 148 160 170 178

Table 7.1 Mean searching efficiency a′ (cm^2/hr) of the indigenous predators on stages of M. tanajoa.

Prey	Predators				
Stages of M. tanajoa	N. teke (ex-mbita)	N. teke (ex-seme)	I. degenerans	Fourth instar larva H.fageli	adult female H. fageli
egg	2.88±0.79	2.44±0.52	3.28±0.87	2.73±1.29	3.60±0.83
larva	2.12±0.89	2.48±0.40	2.86±0.36	2.18±0.36	3.28±0.26
protonymphs	2.13±0.20	2.38±0.27	3.06±0.26	2.96±0.63	3.31±1.10
deeutonymphs	2.02±0.43	2.09±0.45	3.21±0.73	3.28±0.61	3.83±0.79
females	2.11±0.59	2.09±0.39	2.74±0.45	3.49±0.69	3.95±0.59
males	3.87±0.85	4.08±0.93	4.81±0.78	4.64±1.06	4.95±0.66

Table 7.2. Mean handling time (th) (hrs) of each indigenous predator on the six stages of *M. tanajoa*.

Prey	Predators				
Stages of *M. tanajoa*	*N. teke* (ex-mbita)	*N. teke* (ex-seme)	*I. degenerans*	fourth instar larva *H. fageli*	adult female *H. fageli*
egg	0.093	0.092	0.101	0.061	0.033
larva	0.082	0.075	0.091	0.045	0.035
protonymphs	0.098	0.089	0.099	0.067	0.055
deutonymphs	0.113	0.123	0.141	0.085	0.067
females	0.141	0.134	0.152	0.094	0.110
males	0.094	0.083	0..095	0.059	0.048

Table 7.3 Mean predators' egg hatchability (%) per density of each prey stage.

Prey Stage of *M.tanajoa*	Density of prey	Predators			
		N. teke ex-mbita	*N. teke* ex-seme	*I. degenerans*	adult *H.fageli*
eggs	10	100.00a	98.52a	100.00a	75.65a
	20	94.50a	96.65a	100.00a	80.30a
	30	96.00a	100.00a	98.80a	78.00a
	40	98.55a	95.00a	92.60a	84.80a
	50	96.45a	96.33a	95.50a	82.50a
	60	100.00a	100.00a	100.00a	84.64a
larvae	10	55.58b	58.68b	62.55ab	60.00a
	20	52.62b	61.10b	78.64a	52.50ab
	30	60.56ab	72.80a	82.75a	48.45b
	40	64.40ab	76.42a	78.85a	58.75a
	50	50.60b	68.60a	68.60a	65.65a
	60	70.26a	64.50a	86.80a	55.66a
protonyphs	10	70.75a	68.90a	76.52a	62.41a
	20	72.86a	77.50a	82.63a	54.80a
	30	65.54a	78.80a	74.75a	55.65a
	40	70.95a	80.14a	70.45a	61.35a
	50	62.53a	65.30a	68.60a	52.40a
	60	65.40a	64.40a	84.20a	50.55a
deutonymphs	10	88.60a	96.55a	95.10a	70.56a
	20	98.80a	100.00a	92.30a	78.65a
	30	100.00a	98.60a	98.42a	82.50a
	40	98.42a	94.86a	100.00a	80.20a
	50	95.50a	96.56a	100.00a	78.66a
	60	87.65a	100.00a	98.78a	80.30a
females	10	100.00a	96.20a	100.00a	72.60a
	20	96.55a	98.65a	100.00a	78.45a
	30	84.38b	100.00a	94.35a	80.75a
	40	100.00a	100.00a	98.00a	72.35a
	50	98.60a	94.60a	100.00a	88.40a
	60	100.00	100.00a	94.60a	70.60a
males	10	50.35a	48.65a	62.45a	43.55a
	20	58.45a	53.33a	58.60a	58.25a
	30	61.50a	48.35a	55.25a	48.35a
	40	52.42a	50.50a	65.75a	40.47a
	50	51.50a	48.35a	52.80a	42.88a
	60	62.75a	56.80a	51.65a	52.40a

Means in the same column followed by the same letter are not significantly different at $P < 0.05$ (using Duncan's Multiple Range Test, df = 96).

Table 7.4 Mean predator's egg hatchability (%) per prey stage consumed by the female predators.

Stage density	Predators			
	N. teke ex-mbita	N. teke ex-seme	I.degenerans	H. fageli adult
eggs	97.58a	97.75a	97.82a	80.98a
larvae	60.67b	67.02b	76.37b	56.84b
Protonymphs	68.99b	72.51b	76.19b	56.19b
deutonymphs	94.48a	97.75a	97.28a	78.47a
females	96.58a	98.24a	97.83a	77.19a
males	56.16b	51.00c	57.75c	47.65b

8.0 FEEDING PREFERENCE OF FIVE INDIGENOUS PREDATORS ON M. TANAJOA AND T. CINNABARINUS

8.1 INTRODUCTION

Generally in Africa, cassava plantations are often infested with mixed populations of the exotic cassava green mite (C.G.M.), M. tanajoa and the indigenous red spider mites (R.S.M.), T. cinnabarinus. Although, T. cinnabarinus populations never reach damaging levels in the cassava plants, there are common predators of both mites within the same habitant.

Subsequently, it is possible that one prey species is more preferred than the other one. Knowledge of the prey preference is essential when carrying out evaluation of the predators for possible biocontrol of M. tanajoa. It is essential that the final possible candidate predator for biocontrol of M. tanajoa should confine itself or prefer M. tanajoa more than T. cinnabarinus which usually occupies the lower leaves of the cassava plant. Therefore, it was deemed necessary to examine the feeding preference of the five indigenous predators namely, H. fageli, I. degenerans, S. morelletti and two strains of N. teke ex-Mbita and ex-Seme.

8.2 MATERIALS AND METHODS

Cultures of the five predators species, namely, H. fageli, I. degenerans, S. morelletti, N. teke ex-Mbita and ex-Seme strains were routinely maintained on all M. tanajoa stages in the laboratory except N. teke ex-Mbita strain which was mass-reared on artificial diet and alternated with T. cinnabarinus on beans. The prey population was reared as stated in chapter 3 for M. tanajoa whereas T. cinnabarinus was reared on beans.

For the assessment of prey preference, gravid female predators were selected and starved for six house by putting them in a medicine cup with slightly humid filter papers to provide them with the right humidity. The medicine cup was closed with a lid whose portion had been replaced with a fine gauze to provide ventilation. The predators were starved to standardise their hunger state.

Equal numbers of M. tanajoa and T. cinnabarinus (i.e. females and eggs) were placed in cassava leaf disc (25mm diameter) at densities of 20, 30, 40, 50, 60, 70, 80 mite stage/disc. The cassava leaf disc had been placed upside down on wet cotton wool as outlined in chapter 3.

The two prey species were simultaneously offered separately to predators as above at the same densities.

Then one of each female predators was introduced individually onto the leaf disc where the prey species was. All specimens were transferred using slightly moistened camel hair brush. The treatments were replicated eight times. These experiments were conducted in temperature - humidity controlled rooms of 25±1^{0}C and 65+5% r.h. respectively for 24 hours with light throughout the experimental period. The network of webbing produced by the prey species was removed every six hours to facilitate predator movements. At the same time, any prey that had been killed or drowned was counted and replaced to maintain constant density. Eggs of both prey and predator were also removed regularly.

8.3 RESULTS

Prey preference of each predator when M. tanajoa and T. cinnabarinus females offered as single species is given in figure 8.1. Predation rates of each species indicated that predators invariably killed more M. tanajoa than T. cinnabarinus female mites offered as single species. While N. teke strains killed significantly higher numbers of female prey at high densities (50, 60 and 80 mite/disc), I. degenerans killed significantly more female prey of M. tanajoa than those of T. cinnabarinus at low densities (30 and 40 mites/disc) (x^2 = 14.3, df = 6, P < 0.05).

H. fageli killed significantly more M. tanajoa female mites at low densities of 20 to 50 mites/disc than those of T. cinnabarinus. It also killed highly significant number of M. tanajoa at higher densities (60 to 80 mites/disc) than it killed T. cinnabarinus, (x^2 = 18.8, df = 6, P < 0.01). Similarly, S. morelletti consumed significantly higher numbers of M. tanajoa than T. cinnabarinus at medium densities of 40 to 50 mites/disc and high densities and 60 to 80 mites/disc (x^2 = 18.4, df = 6, P < 0.01).

Prey preference of the five predators when eggs of M. tanajoa and T. cinnabarinus were offered as single separate species is presented in figure 8.2. The mean predation rates of these predators indicated that N. teke strains, and I. degenerans showed highly significant preference for M. tanajoa eggs than for T. cinnabarinus at both low and high densities (x^2 = 8.2, df = 6, P < 0.01). However, N. teke ex-Seme strain did not show any preference at very high prey density (70 and 80 mites/ disc) at the same level of probability.

On the other hand, H. fageli showed significant preference for M.tanajoa at high densities (x^2 = 11.3, df = 6, P < 0.01). But, this species showed no significant preference at low prey densities when the prey were offered as single species. On the other hand, S. morelletti did not show any significant preference between the two prey species offered as single species although, it consumed more M.

tanajoa eggs than those of T. cinnabarinus at all the densities used (x^2 = 2.2, df = 6, P < 0.05). Furthermore, as single prey species were offered, these predators preferred M. tanajoa to T. cinnabarinus eggs and females.

Prey preference of the five indigenous predators when female prey mites of M. tanajoa and T. cinnabarinus were offered as mixed species is presented in figure 8.3. This figure indicated that N. teke ex-Mbita strain did not show any significant preference between M. tanajoa and T. cinnabarinus mixed equally at all the densities used in this experiment (x^2 = 2.32, df =6, P < 0.05). However, N. teke ex-Seme strain and I. degenerans had significant preference for M. tanajoa even when mixed equally at low and medium densities (30 to 60 mites/disc) (x^2 = 17.8, df = 6, P < 0.05 and 0.01), but they had no significant preference between the two prey species offered equally at high densities (above 60 mites/disc) (x^2 = 2.11, df = 6, P < 0.05).

Furthermore, H. fageli and S. morelletti consumed more female mites of M. tanajoa than T. cinnabarinus throughout all the densities used. However, they did not show any significant preference for M. tanajoa at low densities (x^2 = 0.8, df =6, P < 0.05). On the other hand, at high densities both predators had highly significant preferences for M. tanajoa than T. cinnabarinus female (x^2 = 21.2, df = 6, P < 0.01, 0.05).

Prey preference of five predators when eggs of prey mite were offered as mixed species of M. tanajoa and T. cinnabarinus is presented in figure 8.4. This figure showed that whereas N. teke ex-Mbita strain consumed more eggs of T. cinnabarinus than those of M. tanajoa when the two were offered as mixed species at low densities, these were not significantly preferred. Nevertheless, at high densities this ex-Mbita strain consumed significantly higher numbers M. tanajoa eggs than it feed on T. cinnabarinus eggs (x^2 = 14.6, df = 6, $P < 0.01$).

While N. teke ex-Seme strain had significant preference for M. tanajoa eggs at low densities of 30 and 40 eggs/disc, at high densities above 40 eggs/disc its preference for M. tanajoa eggs was highly significantly different from those of T. cinnabarinus (x^2 = 27.2, df = 6, $P < 0.001$).

Moreover, when the eggs of both prey species were offered as mixed species to the predators, I. degenerans, H. fageli and S. morelletti consumed more eggs of M. tanajoa but they were not significant at low densities (from 20 to 40 eggs/disc). However, these predator species consumed highly significant numbers of M. tanajoa eggs than those of T. cinnabarinus at high densities (60 to 80 eggs/disc) at 1% level of probability (x^2 = 20.3, df = 6, Fig. 8.4).

8.4 DISCUSSION

The foregoing results evidently showed that most of the predators preferred M. tanajoa to T. cinnabarinus adult females and eggs. These predators consumed more eggs of M. tanajoa than they consumed those of T. cinnabarinus. It is possible that these predators ate more eggs of M. tanajoa than those of T. cinnabarinus because eggs of M. tanajoa were smaller than those of T. cinnabarinus. Therefore, each predator needed more eggs of M.tanajoa in order to become satisfied. The same applied to M. tanajoa females which were also smaller than T. cinnabarinus. Therefore, the preference for M. tanajoa could have been because it was easier to catch and subdue since it was smaller in size than T. cinnabarinus. It is also, probable, that this species could have been preferred because it was more nutritious and more palatable than T. cinnabarinus. Van den Berg (1987) had similar results when he tested the preferences of N.idaeus and N. anonymus between M. tanajoa and T. lambardini.

However, these experiments were done using only leaf discs as the arena. The implication here was that these predators could have greater impact on the populations of the cassava green spider mite than on those of T. cinnabarinus at the level of whole leaves on the plants. However, other factors such as preferences of predators for different life stages of the prey species other than adult

females and eggs, predators reaction to the prey species webbing structures as found in T. cinnabarinus and the different spatial distribution of the species on the plant, have definite roles which they play in the determination of the impact of the predators on the pest population in the field.

Although, it is evident that the predators in this experiment preferred M. tanajoa to T. cinnabarinus, in the cassava crop, it is also possible that T. cinnabarinus might provide alternative food supply for them during periods when M. tanajoa is scarce. McMurtry and Scriven (1964) found that pollen and honey dew from mealybug provided alternative foods for Amblyseius hibisci (Chant) during the period of Panonychus citri (McGregor) scarcity in orchards. It also has been reported that phytoseiids with low searching capacity such as I. degenerans and N. teke would be diverted to other food sources during the periods of low density or scarcity of prey (McMurtry and Johnson 1965, McMurtry and Scriven, 1964, 1965). Therefore, at low prey density, preference might not be distinct as it was at high density because of low searching efficiency which had been shown in the previous chapter, that the predators had low researching efficiencies at low prey densities.

In Kenya, spatial distribution of the cassava green mite is limited to the top first eight leaves of the

terminal shoot of "Kibandameno" cassava variety. This distribution might not coincide with those of some of the predators such as I. degenerans (Munthali, 1986). This difference in spatial distribution might force I. degenerans to feed on T. cinnabarinus whose distribution coincides with its distribution, since the two species were in close proximity within the same habitat.

Besides, some of these predators might be exposed to their own predators if they migrated to the top of the plants where the cassava green spider mite normally fed. Moreover, some of these predators such as N. teke strains, which were sensitive to exposure to high temperatures, would not migrate to the top of the plants due to high temperatures which would overheat them. These factors might cause the predators to resort to alternative food sources in order to survive in the field. This implied that predators' preference in the field could be quite different from the one which was observed under laboratory conditions where the prey and predator were confined to small arenas.

Significant preferences exhibited by H. fageli and S. morelletti towards high density of female prey was probably, because of their nutritional requirements since these predators were ovipositing females. It is postulated that these female mites possessed either hormones or vitamins which enhanced growth and egg-maturation of these predators.

McMurtry (1977) described these coleopterans as being species specific predators of tetranychid mites. He added that these beetles require relatively high densities of mites for development and reproduction and concluded that they can effectively reduce heavy infestations of mites to low levels. Other workers with similar observations were Collyer (1964), Dosse (1957) and Fleschner (1958).

Chant (1963) pointed out that predators such as H. fageli and S. morelletti which responded by feeding directly on the reproductive stages such as adult females should bring about population decline rapidly. In this study the response to increases in prey density and preferences of H. fageli and S. morelletti for M. tanajoa demonstrated that their high food requirements probably, limited their potential to maintain mite populations at low densities.

However, the phytoseiid predators such as N. teke strains and I. degenerans have been shown to perform very well at low prey mite densities and they have shown preference for M. tanajoa. It is recommended that phytoseiid predators should be introduced at a later stage after the release of the two coleopteran predators, namely, H. fageli and S. morelletti, so that the phytoseiid predators would maintain the mites at low densities (McMurtry et al 1970; Takafuji and Chant 1976).

Besides, the observation that phytoseiids consume relatively fewer spider mites and therefore, can survive at low prey densities (McMurtry et al, 1970), require other adaptations which would enable them to locate their prey. Sabelis and Dicke (1985) and Hislop and Prokopy (1981) reported that phytoseiid predators were attracted to their prey colonies. Fransz (1974) and Sabelis (1981) concluded that the phytoseiid predators have the ability to move about within the webbing structures of their prey. Thus, their preference for a prey mite population such as M. tanajoa has very important implications with respect to their use in biological control of the cassava green spider mite.

Moreover, at very low prey densities most predators preferred T. cinnabarinus. This was probably, because both T. cinnabarinus females and eggs were big in size and could easily be found with minimum searching effort. Subsequently, T. cinnabarinus could easily be allocated than M. tanajoa females and eggs. Therefore, the prey size influenced predators preference at low prey density.

However, it must have been difficult to handle T. cinnabarinus females such that the small sized predators such as N. teke strains which were also less aggressive than I. degenerans, gave up before captivating most prey. This was particularly observed at high prey densities in mixed species where N. teke strain simply preferred to capture M.

tanajoa rather than T. cinnabarinus. Therefore, it is postulated that preference for M. tanajoa was influenced by handling time due to the prey sizes i.e. the smaller and less aggressive the predator was, the lower was its preference for the larger prey species, T. cinnabarinus and vice visa.

Therefore, this study has revealed that these predators' preference for M. tanajoa rather than T. cinnabarinus, was influenced by these predators' functional responses to the densities offered as both single and mixed prey, suitability of the prey size and stage used in the experiment, and predators' own inherent behavioural characteristics such as aggressiveness, searching efficiency and handling capacity.

Fig. 8.1

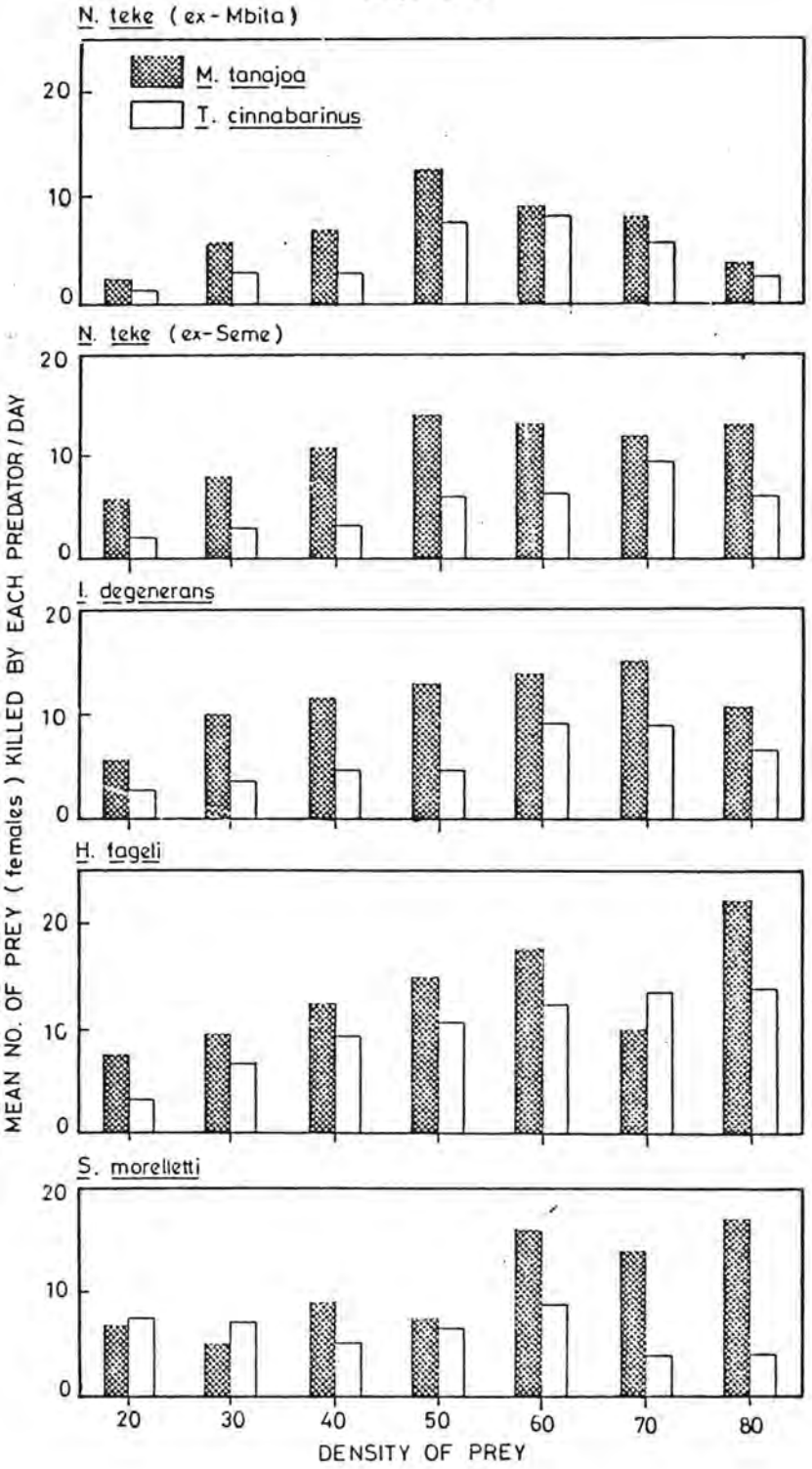

N. teke (ex - Mbita)
M. tanajoa
T. cinnabarinus
N. teke (ex-Seme)
I. degenerans
H. tageli
S. morelletti
MEAN NO. OF PREY (females) KILLED BY EACH PREDATOR / DAY
DENSITY OF PREY
0
10
20
30
40
50
60
70
80

Fig. 8.2

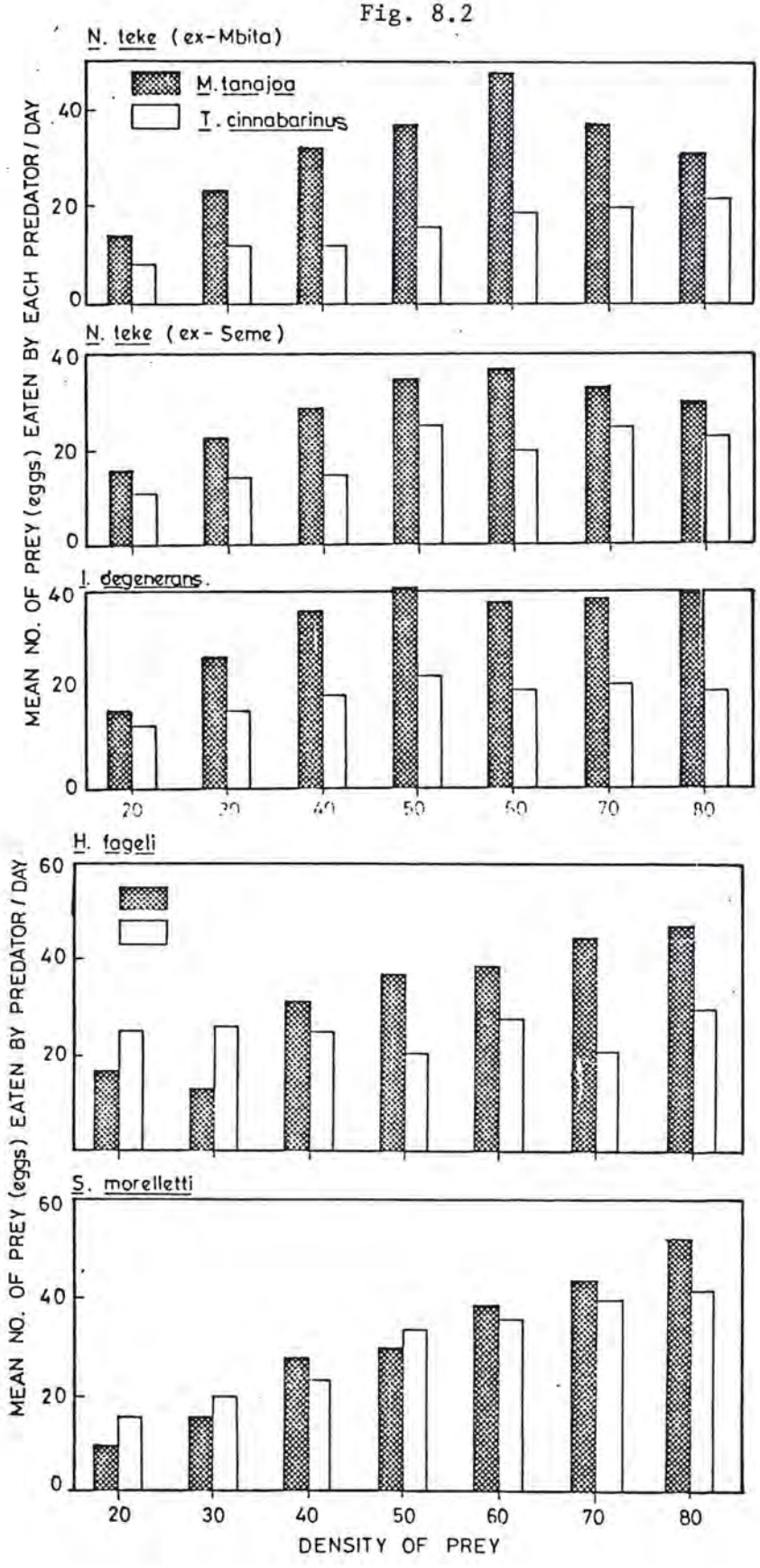

N. teke (ex-Mbita)
M. tanajoa
T. cinnabarinus
N. teke (ex-Seme)
I. degenerans.
H. fageli
S. morelletti
MEAN NO. OF PREY (eggs) EATEN BY EACH PREDATOR / DAY
MEAN NO. OF PREY (eggs) EATEN BY PREDATOR / DAY
0
20
40
60
20
30
40
50
60
70
80
DENSITY OF PREY

Fig. 8.3

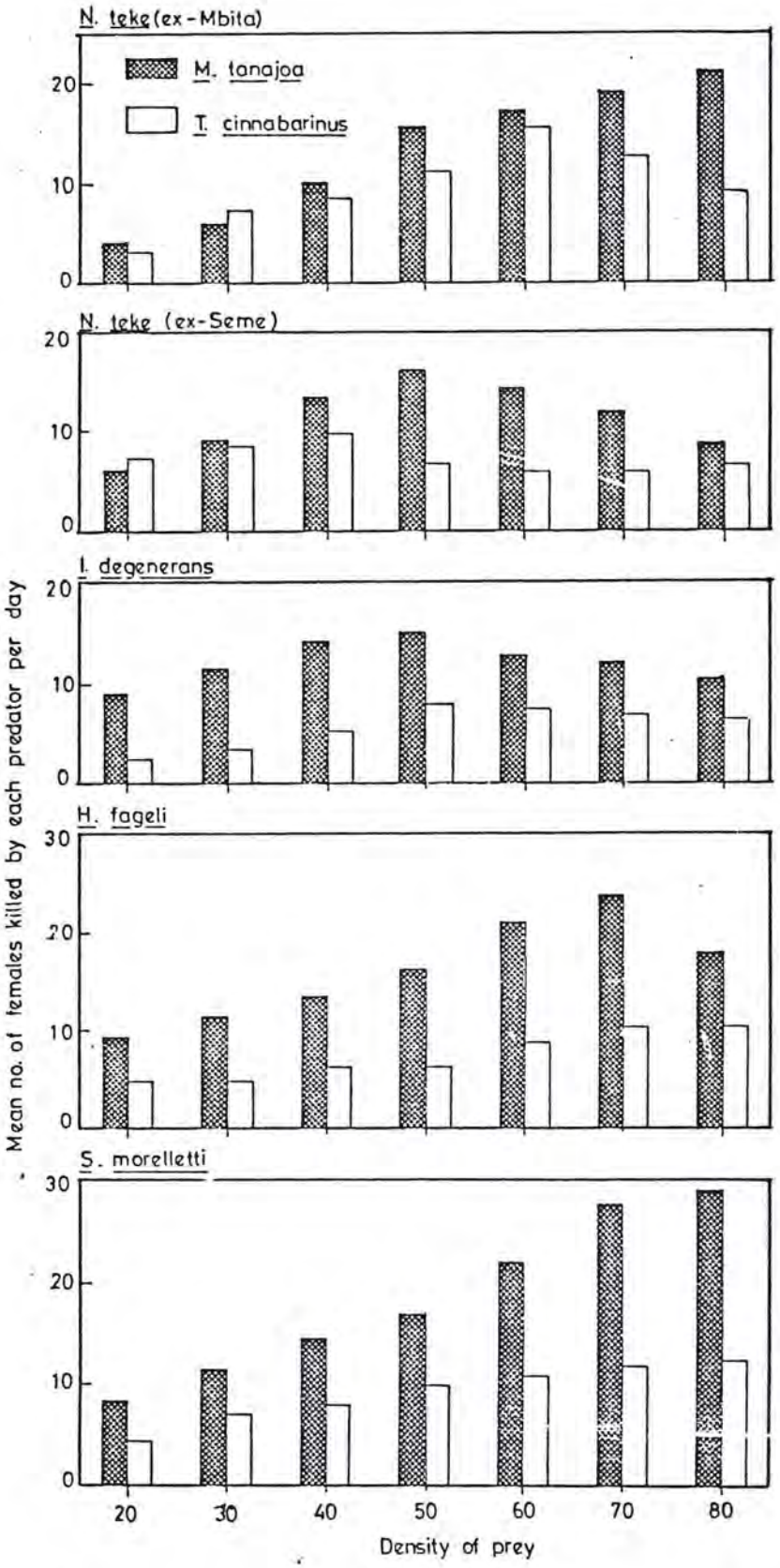
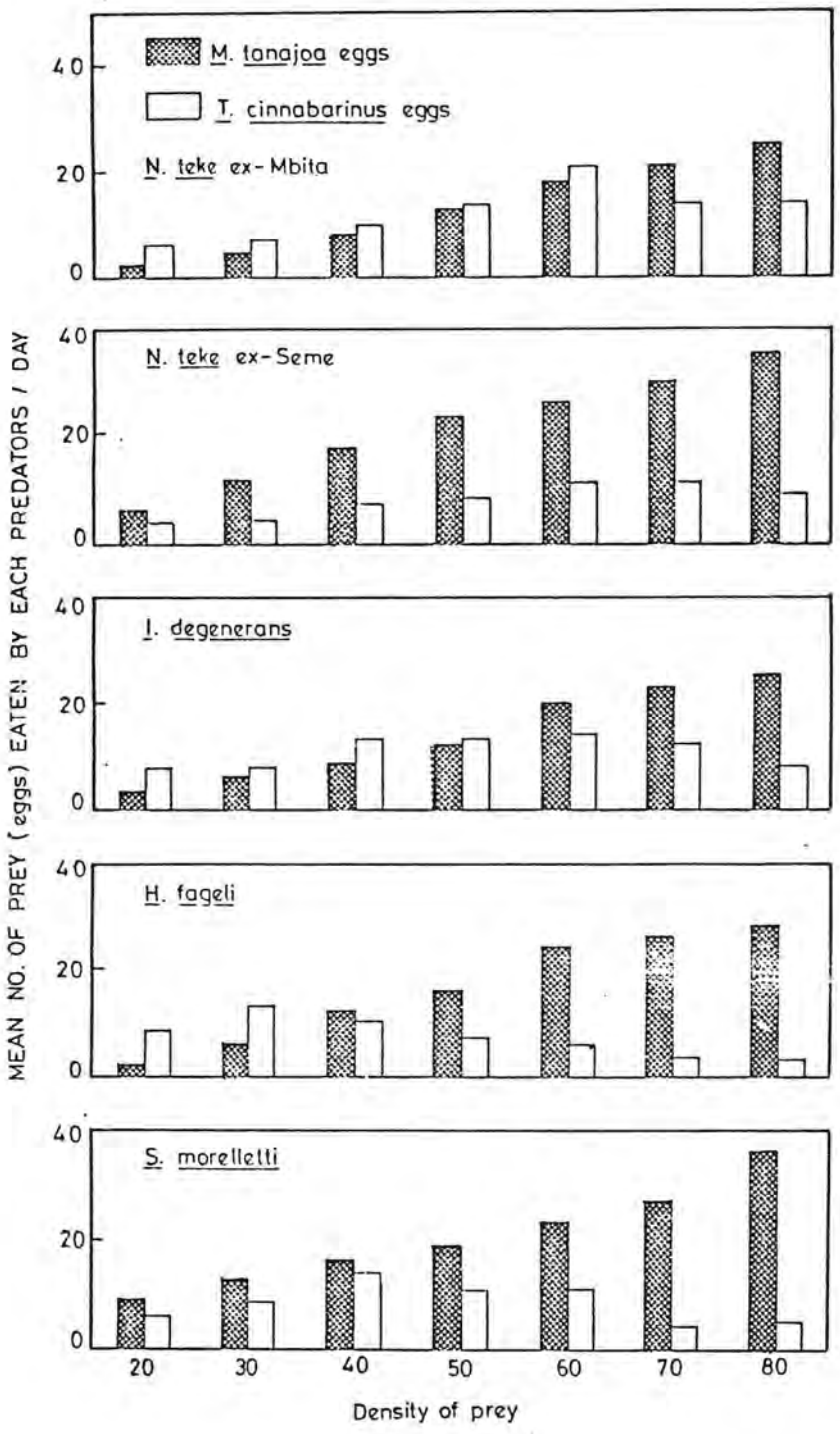

N. teke (ex-Mbita)
M. tanajoa
T. cinnabarinus
N. teke (ex-Seme)
I. degenerans
H. fageli
S. morelletti
Mean no. of females killed by each predator per day
Density of prey
0
10
20
30
40
50
60
70
80

Fig. 8.4


M. tanajoa eggs
T. cinnabarinus eggs
N. teke ex-Mbita
N. teke ex-Seme
I. degenerans
H. fageli
S. morelletti
MEAN NO. OF PREY (eggs) EATEN BY EACH PREDATORS / DAY
0
20
40
20
30
40
50
60
70
80
Density of prey

9.0 POPULATION SUPPRESSION OF M. TANAJOA USING ITS INDIGENOUS PREDATORS

9.1 INTRODUCTION

Three indigenous predators of M. tanajoa namely, I. degenerans and N. teke (ex-Seme and ex- Mbita strains and H. faqeli were found feeding on M. tanajoa in the field. They were transferred to the laboratory where they were reared on M. tanajoa except N. teke, ex-Mbita strain which was mass reared on artificial diet at the International Centre for Insect Physiology and Ecology (ICIPE) at the Mbita Point Field Station (MPFS). Nevertheless, it was maintained on M. tanajoa, the natural host, for more than two generations in order to that it may recognise its prey during the experimentation.

However, other researchers had also recognised that some of these predators could be used as biocontrol agents of M. tanajoa. Munthali (1986) reported complete suppression of M. tanajoa in Malawi by the phytoseiid, I. degenerans. During his field observations he recorded reduction from 300 to 5 mites per leaf within a month. Nonetheless, Ndayiragije (1986) during his surveys of local enemies in Burundi found a complex of indigenous predators on M. tanajoa and reported that this complex was not able to regulate the cassava green spider mite effectively. Markham

and Robertson (1986) reported that although there was close association of both I. degenerans and H. fageli with populations of M. tanajoa in Kenya, Malawi and Rwanda, they did not suppress the pest populations. However, they recognised that there were many other species of the family Phytoseiidae in Kenya some of which could be used to suppress this pest. Robertson (1986) reported that H. fageli was among the predators of M. tanajoa which he had encountered during his field survey. Nyiira and Mutinga (1980) indicated that although they had encountered complexes of indigenous predators of M. tanajoa apparently, these complexes of predators had no appreciable impact on pest populations.

In view of the inconsistency expressed by the foregoing reports, it was essential that specific experiments should be designed and conducted with the objective of assessing the efficiency of these indigenous predators individually and as complexes to justify the possibility of using them as biocontrol agents of M. tanajoa.

9.2. MATERIALS AND METHODS

9.2.1 INDIVIDUAL PREDATOR SPECIES SEPARATELY

Experiments were conducted in cages of 1m x 1m x 1.5m (length x width x height respectively) which were made of wooden frames covered with fine nylon netting material.

Attached at the bottom of the frame was a wooden base on which a potted plant was placed.

Cassava cuttings of 'Kibandameno' variety were planted in plastic pails (15-litre sizes) which had been filled with sandy loam soil. The pails were placed in the cages and watered regularly. When the cuttings had sprouted and the plants had grown to a height of about 1 meter, the shoots had about 20 mites-free leaves each. Then, one shoot with between 20 and 22 leaves was selected per plant while the extra shoots were removed.

Fifty adult females of the cassava green spider mite (CGM) were randomly released onto each shoot by use of a camel hair brush. These M. tanajoa female mites were left to reproduce for 15 days which gave rise to about one generation. The number of female mites were then counted using a portable binocular microscope (Wild 5A)., The microscope was mounted on a table and the pail with the plant was placed on its side on the same table while the leaf was turned upside down and clipped onto the microscope's stage (X120 Magnification). Initial count of CGM females was made before releasing the predators onto each leaf.

Initial and subsequent sampling of M. tanajoa adult female mites was done by counting them on leaves one to five per plant using the binocular miscroscope as outlined above.

Ten pairs of freshly emerged and copulating males and females of each predator were picked from the stock culture and placed onto clean leaf disc (to ensure that equal numbers of both sexes were collected and released). They were starved for six hours before being released onto the leaves of each plant individually. Each treatment was replicated five times besides, maintaining five replicates of the check (control where no predator was released). Thereafter, the plants were sealed in the cages and sampling of both prey and predators was done at weekly intervals for six weeks.

Adults and nymphs of each phytoseiid predator (active stages) were counted per plant using the binocular microscope for examining the undersides of all the leaves. However, adults and larvae of H. fageli being visible to the unaided eye, were counted by just turning the undersides of the leaves within the cages and recording their numbers.

9.2.2. COMBINATIONS OF PREDATOR SPECIES

In another experiment, combinations of predator species, N. teke + I. degenerans; N. teke + H. fageli;

I.degenerans + H. fageli were used as the treatments (N. teke ex-Mbita was used in this experiment). Ten pairs of each species were starved for six hours before being released onto each plant and a check or control i.e. without any predators was maintained. Each treatment was replicated five times. Sampling of M. tanajoa females and the predators were carried out at weekly intervals using sampling procedure as outlined above in chapter 9.2.1. The data obtained was analysed by computer for Anova, Dancan's multiple range test and correlations.

9.3 RESULTS

9.3.1. INDIVIDUAL PREDATOR SPECIES SEPARATELY

The mean number of M. tanajoa females (hereafter referred to as "mite") on plants with different predator species individually/separately is given in Table 9.1. There were significant differences among the means of mites on the plants with different predators ($F=8.8$, $df=4,16$, $P<0.01$). However, there were no significant differences in the number of mites in the plants before the release of predators. Nevertheless, the highest number of mites per plant, were significantly higher than those on the plants with predators (DMRT, $df=16$, $P<0.05$) throughout the six weeks, was recorded on the control i.e. the plants without predators throughout the sampling period. Moreover, while

the number of mites on plants without predators increased to a maximum of 735.2 mites/plant during the sixth week, those on plants with predators decreased with the lowest mean number of 40.1 mites/plant occurring where H. fageli had been released.

Although, plants with ex-Seme strain of N. teke had significantly lower mean number of mites than those with N. teke ex-Mbita strain during the first week, the two strains were not significantly different during the second and third weeks. Nevertheless, during the fourth, fifth and sixth weeks, plants with N. teke ex-Mbita had significantly lower mean number of mites than those on plants with N.teke ex-Seme strain (Table 9.1, DMRT, df=16, $P<0.01$).

Whereas plants with H. fageli had significantly lower mean number of mites than those with I. degenerans during the first week. But there were no significant differences between mean number of mites on the plants with either H. fageli or I. degenerans during the remaining four subsequent weeks (Table 9.1, DMRT, df=16, $P<0.01$).

Apparent reduction (percent) of the mean number of mites by each predator for the six weeks is given in table 9.2. (The figures are "apparent" reduction because some mites might have emigrated or had natural death and fallen off the plants). Apart from the plants without predators where the mites increased in number (symbolised by "+"

sign), all the plants with predators had high initial reduction percent during the first and second weeks. Thereafter, the percentage reduction of mites decreased to a minimum. However, in some cases, the mean number of mites increased more than those in the previous week. Moreover, mites increased even on plants with predators during the last week. Whereas N. teke strains had their highest percentage reduction during the first week, I. degenerans and H. fageli had their highest percentages reduction of mites during the second week after release (Table 9.2).

Mean number of predators per plant per week during the six weeks after release is given in table 9.3. There were significant increases in the mean number of predators per plant per week. There were no significant differences between the mean number of N. teke strains during the first week. However, during the same week, it was shown that the mean numbers of both N. teke strains were significantly higher than those of either I. degenerans or H. fageli ($F=6.4$, $df=3,12$, $P<0.05$ and DMRT, $df=12$, $P<0.01$).

Whereas, N. teke ex-Mbita attained its peak density of 40.12 active stages/plant during the second week, ex-Seme strain attained its peak density of 46.85 active stages/plant during the third week. However, I degenerans and H. fageli attained their peak densities of 55.10 and

46.33 active stages per plant respectively during the third and fourth weeks respectively.

The apparent increases percent of each predator per plant is given in table 9.4. The apparent numerical increases of all the predators increased substantially during the first and second weeks with the highest percentage increase occurring during the first week except H. fageli whose highest percentage increase (29.42% larvae and adults/plant) occurred during the second week. While N. teke ex-Seme strain increased by 81.10% during the first week, it began to decrease from the previous percentage by the third upto the sixth week. While N. teke ex-Mbita strain and I degenerans attained their highest percentage increases of 56.55 and 61.06% during the first and third weeks respectively, thereafter ,they began decreasing. H. fageli had its maximum percentage increase of 29.42% during the second week but started decreasing during the fifth week.

The prey mites were significantly correlated with the predators H. fageli ($r = -0.846$), I. degenerans ($r=-0.885$, $df=3$, $P<0.01$) N. teke ex-Mbita ($r=-0.980$) and ex-Seme ($r=-0.991$, $df=3$, $P<0.01$). On the other hand, mites on control plants were positively correlated ($r=0.861$, $df=5$, $P<0.01$) with exposure period i.e.the mites increased with the period of exposture.

9.3.2. COMBINATIONS OF PREDATOR SPECIES

The mean number of mites counted before and after release of combined predators during the six weeks is given in table 9.1. This table indicated that there were highly significant differences among the mean numbers of mites on the plants with various combinations of predators ($F=18.8$, $df=3,12$, $P<0.01$). They had significantly lower mean number of mites than those without the predators. This phenomenon occurred throughout the sampling period of six weeks (DMRT, $df=12$, $P<0.05$).

However, during the first and second weeks, plants with combinations of predators did not have significant differences among the mean number of mites per plant except *N. teke* + *I. degenerans* combination. This combination of *N. teke* + *I. degenerans* was significantly lower than the other two combinations in the second week (DMRT, $df=12$, $P<0.05$). During the fourth to sixth weeks, plants with a combination of *N. teke* + *I degenerans* had significantly higher mean number of mites than those with either a combination of *H. fageli* + *I. degenerans* or *H. fageli* + *N. teke*. (Table 9.5, DMRT, $df=12$, $P<0.01$).

Further, plants with combinations of *H. fageli* + *I. degenerans* and *H.fageli* + *N. teke* had their lowest mean number of mites (39.8 and 76.6 mites/plant respectively) during the sixth week, while plants with a combination of *N.*

teke + I. degenerans had its lowest numbers (178.4 mite/plant) during the third week.

Apparent reduction (percent) of weekly mean number of female mites by combinations of predators is given in table 9.6. The highest percentage reductions of mites were recorded on plants with combinations of N. teke + I. degenerans with 47.14% and H. fageli + N. teke with 43.50% reductions. Mites on control plants increased to a maximum of 47.72% during the second week. However, the mites began to decrease on the same plants upto 7.46% from the third week onwards. Whereas the mites on the plants with predator combinations of H. fageli + I. degenerans had high initial reduction of 47.14% the mites increased from 11,38% in the fourth week to 14.13% during the sixth week.

Numerical increases of predator combinations during their use as biocontrol agents of M. tanajoa is given in table 9.7. This table indicated that there were no significant differences among the mean numerical increases of all the predator combinations during the first week ($F=2.11$, $df=2,8$, $P<0.05$). However, during the second week the mean number of N. teke + I. degenerans (50.25 active stages) was significantly higher than those of H. fageli + N. teke (23.75 active stages). But, numerically the combination of H. fageli + I. degenerans (31.75 active stages) was not significantly different from the combination

of H. fageli + N. teke (23.75 active stages) (DMRT, df=8, P<0.05). Furthermore, during the third to sixth week, mean numbers of predator combinations of H. fageli + I. degenerans and I. degenerans + N. teke were not significantly different among themselves but were different from that of N. teke + H. fageli (Table 9.7, DMRT, df=8)

Besides, table 9.7 showed that the mean number of a combination of H. fageli + I. degenerans increased steadily from 24.90 to 83.5 active stages/plant during the first to the fifth weeks respectively, and then declined to 78.50 active stages during the sixth week. But the mean number of H. fageli + N. teke and N. teke + I. degenerans increased steadily from first to fourth weeks (from 19.25 to 56.00 and 28.5 to 82.75 active stages per plant respectively) and then decreased to 31.75 and 72.50 active stages respectively in the sixth week.

Percentage numerical weekly increases of predator combinations is given in table 9.8. Whereas the percentage weekly increase of a combination of N. teke + I. degenerans (76.32%) occurred early during the second week, those of H. fageli + I. degenerans (71.81%) and H. fageli + N. teke (96.84%) were recorded during the third week. While all the predator combinations increased initially except that of H. fageli + N. teke which decreased by 3.75% in the first week, this combination further decreased markedly during the fifth and sixth weeks.

Numerical increases of the predators individually in the combinations is given in table 9.9. This table showed that in the combination of H. fageli + I. degenerans was more than H. fageli during all the sampling periods. Similarly, in the combination of H. fageli + N. teke, N. teke was higher in number than H. fageli until the third week when the number of H. fageli became more than that of N. teke upto the sixth weeks. Initially, in the combination of I. degenerans + N. teke, the two species were about equal in number but during the second to sixth weeks, the number of I. degenerans increased and it remained higher than that of N. teke throughout the sampling period.

9.4. DISCUSSION

9.4.1 INDIVIDUAL PREDATOR SPECIES SEPARATELY

The significant differences observed between the mite population on plants with predators and those without predators indicated that the predators which were used reduced the mites considerably. For example, I. degenerans and H. fageli reduced the mite population by 77.22% and 44.57% respectively within two weeks.

Besides, these two predator species having had considerable initial impact, they maintained the pest population at very low densities throughout the remaining four weeks. This was confirmed by significantly negative relationship between the predators and the mite population densities. Probably, high initial reductions of mite densities were due to the fact that the predators had been starved and they were introduced as pairs were at the peak of their reproductive phases physiologically (preoviposition and oviposition). The high predation rates of these predators were, therefore, influenced by hunger and physiological state and nutritional history of the predators.

Eveleigh and Chant (1981) reported that predation rate was influenced by hunger state and nutritional history i.e.

if the predators had been feeding on the same host and it was a major host, their predation rates become enhanced considerably. These findings also confirmed those of Mori and Chant (1966) and Sabelis (1981) who found that feeding capacity increased if the predators which they used were hungry.

Since the predators which were released were newly emerged gravid females (because they were picked up during copulation) it implied that during the first and second weeks after release they were still developing and ovipositing eggs as well as continuing copulation (where multiple mating is required as found in I. degenerans (Amano and Chant 1986)). It has been reported that mating is necessary for reproduction in most phytoseiid mites and its success depended largely on searching effort of the males (Amano and Chant, 1978a). Takafuji and Chant (1976) and Thurling (1980) have demonstrated that gravid female phytoseiids exhibited highest predation rates than all the other developmental stages.

Variations in mite densities in plants with N. teke strains were not pronounced because both strains had short developmental period and generation time (in this work). This inherent characteristic coupled with physiological and hunger state as stated above enabled these strains to attain some initial impact and to reduce the prey density by

exhibiting high feeding capacity with subsequent rapid numerical increases of their populations.

However, N. teke was characterised by "disappearance" from the site of release (Markham, per. Com.). These strains probably, emigrated and either fed on other substances or prey, or redistributed themselves more randomly than that of the prey, since they had low tendency to congregate on prey infested leaves. Amblyseius hibisci Chant was found to distribute itself more randomly than the prey and had a low tendency to congregate on prey infested leaves (McMurtry et al, 1984).

Besides, it is postulated that nutritional history might have affected the performance of N. teke ex-Mbita strain. Although, this strain was reared on M. tanajoa for more than two generations, it had been reared predominantly, on artificial diet at MPFS laboratories for many generations (Ochieng', Pers. Com.). Probably, it never recognised and enjoyed feeding on M. tanajoa as did N. teke ex-Seme strain which had been collected from the field while feeding on M. tanajoa and was reared on the same prey. Moreover, it was noted that N. teke ex-Seme strain was more aggressive than ex-Mbita strain (Pers. Observ.) because it had been feeding on M. tanajoa.

The magnitude of the impact of I. degenerans during the second and subsequent weeks were mainly due to its short developmental period and generation time (in this study) which enabled its population to increase numerically to very high density. Subsequently, it was able to consume large numbers of mites and thereby reduce the mite population to low density. Thus, its high functional response to high density of prey contributed to the high numerical response as observed earlier in chapter 7. Since this predator was capable of building its population rapidly, subsequently it was capable of reducing the prey population from 465.4 to 40 mites/plant whithin 5 weeks. Munthali (1986) had observed similar fast population increases of I. degenerans with subsequent reduction of high density of mite populations of M. tanajoa from 300 to 5 mites/leaf within a month.

However, as the density of I. degenerans increased, there must have been interference, high incidence of mortality and emigration, all of which resulted in the reduction of the predation pressure from the predators. Subsequently, the density of the prey mites began to increase in response to low predation pressure.

Initial impact produced by H. fageli on its prey population was an evidence of its voracious feeding capacity which indicated that it required high numbers of M.tanajoa for its egg-development and oviposition as noted by McMurtry

et al (1969). Being a staphylinid such as Oligota minuta Cameron which was identified to be used as a biocontrol agent for M. tanajoa in East Africa by Yaseen et al (1982), this predator had high capacity of consumption for tetranychid mites.

However, H. fageli apparently, did not continue to exert the same predatory pressure because the mite density began to increase instead of decreasing further. Obviously, low mite densities demanded very high searching efficiency which probably, triggered H. fageli to emigrate in search of more profitable patches of high density of prey elsewhere. Evidently, H. fageli had comparatively low numerical responses although it had reduced the mite populations to very low densities after six weeks. This phenomenon indicated that, although, this predator had high functional response, its numerical response was low see in chapter 7. Therefore, it was envisaged that its low numerical response is probably, due to its inherent low reproductive capacity together with its long developmental period (pers. observ.).

The occurrence of significant negative correlations of H. fageli, N. teke and I. degenerans with their respective mite populations confirmed that while the prey population density decreased, the predator populations increased. On the other hand, the mite densities on the control plants were significantly and positively correlated with the exposure period and this indicated that the mite densities on these plants increased throughout the sampling period unhindered. This, further emphasised the impact of predators in suppressing this pest in cages.

The highly significant reductions of the prey mite populations during the first and second weeks indicated that predator combinations can have much stronger initial impact on the prey populations than the individual species. Furthermore, if the ratio of the predator species in the combinations were just "right" then the searching efficiency and attacking rate were greatly enhanced in order to suppress the mite population. Eveleigh and Chant (1982a) had similar observations. Therefore, I. degenerans + H. fageli combination efficiently reduced the mite population density and maintained it at a fairly low level without any significant prey mite increases during this period.

These two predator species exploited the situation by exhibiting their different behavioural attributes. For example, I. degenerans has high attacking rate (Eveleigh and Chant 1982a) at high prey density and H. fageli had high prey requirement hence high prey consumption capacity (McMurty, 1977). Therefore, this combination of H. fageli which has a high prey requirement and attacking rate released together with I. degenerans had considerably strong impact on the prey population resulting in very high percentage reductions of the mite population.

However, as the mite density decreased the percentage reduction also decreased during the sixth week. This phenomenon indicated that both predators could not exert

appreciable predatory pressure on the mite population at low density because the prey mites were now too few for them to locate. Thus, this showed that although, both I. degenerans and H. fageli had high prey requirements, they had low searching capacities as shown in demonstrated in chapter 7. This finding supported Huffaker et. al (1970) hypothesis that predators of spider mites with high food requirements do not necessarily have correspondingly high searching efficiencies. Eveleigh and Chant (1981 and 1982b) had similar findings with respect to I. degenerans.

On the contrary, Sandness and McMurtry (1970) found that at very high prey densities some phytoseiid predators ceased feeding whenever they were disturbed by the prey bumping into them. Further, they reported that in some cases, the predator resumed searching and attacked the interferring prey. This phenomenon led to the predator killing more prey in order to reach satisfaction (Satiation).

Interference also occurred when density of the predators was high and this resulted in emigration from the site of release (Pers. observ.). From those observations it is possible to postulate that interference could act as a mechanism which reduced competition for food when conditions limited free dispersal in the habitat. However, when dispersal was not restricted, interference would be relaxed

by emigration process or dispersal to other areas of low predator density (Huffaker, 1958; Takafuji and Chant 1976; Takafuji, 1977; Hassell, 1971).

However, I.degenerans persisted even at low prey densities because phytoseiids do survive at low mite consuming very low prey densities by consuming very few mites (McMurty et al. 1970). McMurtry, (1977) also found that I. degenerans showed marked numerical response and increased fairly well at low prey density because it fed readily on pollen. Thus, it was possible to find high population densities of *I.* degenerans with low prey mite densities. This flexibility in dietry enabled I. degenerans to reproduce even at low prey density. Although, this attribute ensured the presence of this predator, it could also be a disadvantage because I. degenerans might not have any impact on the prey population just because it would be feeding on very few mites and/or on pollen and other alternative food sources.

Moreover, Takafuji and Deguchi (1980) noticed that some female predators such as Amblyseius species had tendency to move away from low density areas in search of new high density patches. N. teke had a similar tendency of wondering away from the area where the prey were. This explained why the populations of N. teke strains decreased very fast from the site of release and leaving only a few

female predators on the plant. This is, however a beneficial adaptive behaviour which caused her to leave some food for her progeny which had low locomotory ability but they require food for their growth and development. Although, it had also been observed in another study that juveniles of N. teke ex-Seme were very efficient in attacking and killing the prey mites (Pers. observ.). Other workers have had similar observations of parent predator emigration and concluded that these emigrations resulted in local instability of predator-prey interactions. This has been shown to be the case with many phytoseiid predators especially those specialised on spider mites (Takafuji et al, 1983; Sabelis and Laane, 1986; Nachman, 1981, 1987).

In conclusion, it is postulated that these indigenous predators were capable of suppressing M. tanajoa population in cages, although, their performance in the field situation was not clear. The observed temporal fluctuations of the prey and its predators which resulted in the establishment of characteristic oscillations of typical acarine prey-predator system similar oscillations were obtained by Fransz (1974) working with T. urticae and M. occidentalis , Rabbinge (1976) who delt with Panonychus ulmi and A. potentillae ; Dover et. al, (1979) working with P. ulmi and A. fallacis; and Nachman (1981) who studied T. urticae and P. persimilis. They found that population densities of both

prey and their predators reflected a highly interactive and dynamic system of prey and its predators.

Table 9.1 Mean number of M. tanajoa females counted before and during its control with four predator species individually /separately in cages.

Predator Species	Mean number of mites per plant (±SE) Sampling period (weeks) 0	1	2	3	4	5	6
Control (check)	491.2±4.6a	480.6±4.2a	594.5±3.5a	615.3±2.4a	702.9±2.5a	718.2±4.8a	735.2±4.0a
N.teke (ex-seme)	499.3±7.2a	414.5±4.4b	385.2±3.2b	280.5±2.4b	278.4±3.4c	300.6±2.6c	317.5±1.5c
N. teke (ex-Mbita)	459.8±5.4a	309.8±2.0c	338.4±1.8b	324.2±2.6b	341.0±1.4b	384.6±3.2b	398.4±4.8b
I. degenerans	465.4±4.6a	400.4±4.0b	91.2±4.2c	80.2+4.2c	72.6+1.6d	88.8±2.5d	93.6±1.4d
H. fageli	488.8±6.4a	298.2±2.4c	165.3±2.6c	111.8±1.5c	46.2±1.2d	40.1±1.8d	56.8±1.5d

Means in the same column followed by the same letter are not significantly different at $P<0.05$, df = 16, (Using Duncans Multiple Range Test).

Table 9.2. Apparent reduction (%) in weekly mean numbers of M. tanajoa female by each predator species.

Predator	Percentage reduction of female mites per plant per week (Sampling period (weeks))					
Species	1	2	3	4	5	6
Control	+2.28	+23.70	+3.50	+14.24	+2.18	+2.37
N. teke (ex-Seme)	16.98	7.07	27.1	0.75	5.62	+3.45
N.teke (ex-Mbita)	32.62	+9.10	4.20	+5.49	+12.46	+3.59
I.degenerans	13.97	77.22	12.06	9.48	+22.31	+5.41
H. fageli	38.99	44.57	32.37	59.68	13.20	+41.65

Numbers preceeded by '+' sign are percentage increases of the previous means.

Table 9.3 Numerical increases (densities) of the four predator species for the control of M. tanajoa in Cages.

Predator Species	Mean number of predator species (±SE)/Plant Sampling period (weeks) 1	2	3	4	5	6
N.teke (ex-Mbita)	36.22±4.1a	40.12±2.3a	38.62±1.5b	35.45±1.2b	29.57±2.1b	27.35±1.5b
N.teke (ex-Seme)	31.31±2.0a	36.42±3.1a	46.85±1.8a	35.25±1.3b	41.62±3.5a	40.87±2.7a
I. degenerans	27.51±2.5b	34.21±2.0a	55.10±3.2a	54.52±3.1a	51.22±3.1a	43.26±2.2a
H.fageli	24.0±2.0b	31.0±2.2a	37.52±3.2b	46.33±1.8a	39.75±1.5a	35.00±3.0b

Means in the same column followed by the same alphabetical letter are not significantly different ($P \leq 0.05$) (Using Duncans Multiple Range Test, df = 12).

Table 9.4. Percentage numerical increases of each predator species during their use as biocontrol agents of M. tanajoa in cages.

Predator Species	Percentage numerical increases of each predator/week					
	Sampling period (weeks)					
	1	2	3	4	5	6
N.teke (ex-Seme)	81.10	10.76	-3.74	-8.21	-16.59	-7.51
N. teke (ex-Mbita)	56.55	16.32	28.64	-24.76	-18.07	-1.80
I. degenerans	37.55	24.36	61.06	-1.05	-6.05	-14.88
H. fageli	20.00	29.42	20.80	23.48	-14.2	-11.95

Numbers preceded by '-' sign are percentage decreases from the previous means.

Table 9.5 Mean number of M. tanajoa females counted before and during its control with different combinations of four predators in cages.

Predator Species Combinations	Mean number of mites per plant per week						
	Sampling period (weeks)						
	0	1	2	3	4	5	6
Control	427.4±2.4a	441.7±2.5a	652.5±2.5a	739.5±1.5a	709.4±0.5a	695.3±2.5a	643.4±3.4a
H.fageli + I. degenerans	438.6±3.8a	282.3±1.4b	212.7±1.8b	142.2±1.5c	96.5±2.0c	42.4±1.4c	39.8±1.2c
H. fageli + *N.teke	461.2±4.0a	260.6±1.2b	223.5±1.8b	184.2±1.5b	122.4±1.2c	85.3±2.0c	76.6±1.5c
N.teke + I. degenerans	429.8±3.5a	227.2±1.3b	189.3±1.1c	178.4±1.8b	198.7±2.0b	208.8±1.5b	238.3±2.2b

Means in the same column followed by the same letter are not significantly different at P =0.05 (Using Duncans Multiple Range Test , df = 12).

* N. teke used in this experiment was ex-Mbita strain .

Table 9.6. Apparent reduction (%) of weekly mean numbers of *M. tanajoa* females suppressed by combinations of indigenous predator species in cages.

Predator Species Combinations	Percentage reduction of mites per plant per week					
	Sampling period (weeks)					
	1	2	3	4	5	6
Control	+3.35	+47.72	+13.33	4.07	1.99	7.46
H. fageli + *I.degenerans*	35.64	24.65	33.15	32.14	56.06	6.13
H. fageli + *N.teke*	43.50	14.24	17.58	33.55	30.31	10.20
N.teke + *I. degenerans*	47.14	16.68	5.76	+11.38	+5.08	+14.13

Means preceeded by '+' sign are increases rather than decreases percent.

Table 9.7 Numerical increases of the predators combined during their use as biocontrolo agents of M. tanajoa in cages

Predator Species Combined	Mean number of predators (active stages) combined/plant Sampling period (weeks) 1	2	3	4	5	6
H. fageli + I. degenerans	24.90a	31.75b	54.55ab	76.60a	83.25a	78.50a
H.fageli + N. teke	19.25a	23.75b	46.75b	56.00b	45.45b	31.75b
I. degenerans + N. teke	28.5a	50.25a	65.50a	82.75a	79.75a	72.50a

Mean followed by the name letter of alphabet are not significantly different at $P < 0.05$ level (Using Duncans Multiple Range Test, df=12).

Table 9.8 Percentage numerical increases of the predator species combinations during their use as biocontrol agents of *M. tanajoa* in cages.

Predator Species Combined	Mean number of predators (%) combined/plant Sampling period (weeks) 1	2	3	4	5	6
H. fageli + *I. degenerans*	24.5	27.51	71.81	40.42	8.68	-5.71
H. fageli + *N. teke*	-3.75	23.38	96.84	19.79	-18.84	-30.14
N. teke + *I. degenerans*	42.5	76.32	30.34	26.34	-3.63	-9.09

Mean followed by '-' signs were decreases instead of being increases percent.

Table 9.9. Numerical increases of the predators, N. teke, I. degenerans and H. fageli individually in the combinations during their use to supress M. tanajoa in cages.

Predators Species Combinations	Mean number of predator species individually in the combinations/ plant (±SE) Sampling period (weeks) 1	2	3	4	5	6
H.fageli + I. degenerans	9.50+1.2	8.25±1.4	16.75±2.8	27.75±2.4	23.50±2.5	20.25±1.8
H. fageli +	7.75±0.25	6.50±1.0	19.25±2.1	33.25±3.5	26.75±3.0	20.50±1.0
N. teke	11.50±1.00	17.25±2.0	27.50±3.5	22.75±2.8	18.75±2.0	11.25±2.0
I.degenerans	13.25±1.2	26.75±1.5	35.15±2.5	49.25±1.5	52.50±4.2	47.25±1.5
N. teke	14.75±0.8	23.5±2.8	29.75±2.0	33.50±1.5	27.25±2.5	25.25±2.5

10.0 DISPERSAL CAPACITIES OF TWO PHYTOSEIID PREDATORS OF M. TANAJOA IN SCREEN HOUSES

10.1 INTRODUCTION

In Africa, many predators of the cassava green spider mite have been identified including Coccinellidae, Staphylinidae, Stigmaeidae and Phytoseiidae (Girling et al, 1982; Munthali, 1986; Nyiira and Mutinga, 1980; Yaninek et al, 1987; Van den Berg, 1988; Moutia, 1958; Swirski and Regusa, 1978). Although, some members of these families are supposed to be opportunistic feeders according to Yaninek et al, (1987) during high densities of this mite. Others such as those in the family Phytoseiidae have evolved close relationship with tetranychids and their capacity to control spider mites in many agroecosystems has been well established (Huffaker et al, 1970; McMurtry et al, 1970).

Therefore, it was decided that a study of dispersal capacities of these phytoseiid predators should be undertaken as part of their evaluation for use as biocontrol agents of M. tanajoa. This aspect of these predators had not been studied before in relation to M. tanajoa. Therefore, it is essential to assess the dispersal capacities of I. degenerans and N. teke (ex-Mbita strain) in a spersely and uniformly distributed ecosystem of plants(to facilitate their dispersal).

10.2 MATERIALS AND METHODS

Cassava stem cuttings of (25cm long) "Kibandameno" cassava variety, were planted at the spacing of 1m x 1m apart. One cutting was planted at the centre of the floor (to be used as release site for the predators). Further, the plants were watered regularly at three days intervals. Subsequently, they sprouted within two weeks and attained average number of 20 leaves within six weeks after sprouting.

When the plants were eight weeks old, fifty field collected M. tanajoa females were introduced onto each plant. They were left for two weeks so that the mite population could attain one generation to provide sufficient food source as prey for the predators which were to be released. These prey mites were released randomly onto leaves one to five (counting leaf one as the first fully expanded leaf from the terminal shoot) of all the plants exept the one at the centre. Both the prey mites and the predators were handled using moistened camel hair brush.

On the 15th day, 350 one-day old males and females of I. degenerans and N. teke (ex-Mbita strain) were each released onto leaves one to five of the release plant at the centre of the screen house. Releases were carried out by

attaching the filter paper onto the leaf using a small piece of plastecene. Each treatment was replicated three times.

Observations on the movements of the predators were then made for two hours continuously using a hand lens (10 x magnification) to be sure that they settled down onto the plants. Thereafter, the predators were sampled at 24 hour intervals for 7 days (seven days were used because the offspring were getting mixed up with the parents which were originally released and mortality was increasing).

Predators were sampled by examining each plant shoot individualy by searching method using hand lens. All the predator species were counted per shoot and then the distrance between the shoot and the release plant (central plant) was measured using 5-meter tape measure and recorded.

On the second week, plexiglass panels were cut into 10 x 10 cm pieces and two holes were bored on the two opposite ends. One plexiglass was tied on each wall of the four walls of the screenhouse and greased on the inward side with verselline. These panels were used as traps for I. degenerans, N. teke and M. tanajoa dispersing outwards from the plants to the four compass directions (North, South, East and West). The panels were replaced with new ones every two days although the totals were added on weekly

basis (This was to avoid possible deterioration of specimens and melting of the verselline in hot weather).

The panels with the predators were labelled and transferred to the laboratory where the predators and M. tanajoa stages were counted and recorded using sterio microscope, 'Wild 5A'. Sampling of these predators and their prey was done for eight consecutive weeks starting from 12th August to 30th September, 1988.

The distances travelled each day by the phytoseiid predators from the point of release during the first week, were calculated using Clark (1962) formula:

$$D = \Sigma \left(\frac{d^2}{N} \right)$$

Where D is the distance travelled per day

d is the distance measured from the point of capture to the point of release

N is the number of animals (predators)captured

10.3 RESULTS

10.3.1. DISPERSAL OF I. DEGENERANS AND N. TEKE WITHIN PLOT

Mean number of predators dispersing within a plot as indicated by rate of dispersal, distribution, percentage of dispersers and number retained per plot is given in table 10.1. This table showed that the predators redistributed

themselves among the cassava plants from the site of release at varying rates. On day one, I. degenerans redistributed itself at much higher rate (8.18 predators/shoot) than N. teke (3.08 predators/shoot). Furthermore, whereas I. degenerans' rate of redistribution increased from 8.18 to 12.37 predators/shoot, that of N. teke decreased from 3.08 to 1.12 predators/shoot from the first day to the last day of sampling.

Distances covered by N. teke were longer than those covered by I. degenerans . The distance of 36.61cm covered by N. teke on day one was longer than that of 14.13 cm covered by I. degenerans on the same day ($P < 0.05$). Furthermore, while the distances of N. teke increased to 60.00 cm on the seventh day, those of I. degenerans increased to a peak of 26.97 cm only on day four and then declined to 15.83 cm on the seventh day.

The dispersal rates of each predator (%) among the cassava shoots from release sites indicated that the percentage number of I. degenerans which dispersed from the site of release on day one (3.68%) was lower than that of N. teke (7.00%). While dispersal rate (%) of I. degenerans remained more-or-less constant, fluctuating between 3.0 and 5.5% per day, that of N. teke increased gradually each day upto seventh day (14.89%). It was still dispersing from plant to plant when sampling was terminated. Trends of

dispersal was apparently opposite in the two predator species used in this experiment.

Further, the total number of predator species per plot indicated that higher numbers of I. degenerans were present per plot than that of N. teke (Table 10.1). Initially, large numbers of I. degenerans were retained per plot on first day compared to only 35.50 of the 350 introduced of N. teke which had one large initial reduction immediately on being released on to the plants. After the sharp decrease or reduction thereafter, N. teke had small gradual reductions upto seventh day. However, although both predator species decreased upto fourth day four after release, I. degenerans increased thereafter from 156.0 to 195.5 predators per plot compared with N. teke which declined down to 13.27 per plot on seventh day when sampling was terminated.

10.3.2. Aerial dispersal of M. tanajoa, I. degenerans and N. teke

The mean densities of M. tanajoa and its predators, I. degenerans on the panels and the foliage of the cassava during their outward dispersal from the cassava plot is given in table 10.2. This table shows that M. tanajoa females per shoot increased steadily to a peak of 399.07 ± 0.11 mites/shoot on the fourth week and then declined steadily to 118.87 ± 1.67 (± SE) mites/shoot on the eighth week. There was a significant difference between the

density of mites during the peak period 399.07 ± 0.11 (± SE) mites/shoot and the density during the eighth week (F = 8.15, df = 7, 14, P < 0.01) and DMRT, df = 14. The mean density of the mites trapped on the panels increased with that on the foliage although the initial density on the foliage was 120.20 ± 0.11 mites/shoot while those on the panels were only 8.00 ± 0.31 mites/panel. This table also indicated that the peak density of mites on the panels lagged behind the density on the foliage by one week.

Regression analysis of mites on the foliage and those on the panels indicated that the mites on the panels were positively related to those on the foliage by formula Y= 0.6 + 0.65x, ± SE = ± 0.03 and the relationship was significant at P < 0.015, b = 0.654 df = 13. The mite densities on the panels and foliage were also positively and significatly correlated b = 0.809 (SE = ± 0.025, df = 13, P < 0.016).

On the other hand, the density of I. degenerans on the foliage was lower than that of the mites on the foliage but both the mite and its predators attained peak densities of 399.0 and 55.53 per shoot respectively on the fourth and fifth weeks respectively on the foliage (table 10.2). The density of I. degenerans is related to the density of the prey mites on foliage by Y = 27.0 + 0.85x, SE = ± 0.04). The relationship with b = 0.846, df = 13 was significant

at $p < 0.01$. This indicated that the association was probably, density dependent.

Further, the density of I. degenerans on the panels increased at the same time with that on the foliage. The peak density of I. degenerans on the foliage and panel occurred at the same time and both were positively correlated ($b = 0.795$, $SE = \pm 0.098$, $df = 13$, $P < 0.018$). Besides, regression analysis to confirm whether the dispersal was density dependent was significant, $b = 0.683$, ($SE = \pm 0.62$, $df = 13$, $P < 0.018$).

Movement of M. tanajoa, and I. degenerans outward of the screen house to the four compass directions at MPFS is given in table 10.3. This table indicated that when the dispersal directions of M. tanajoa and I. degenerans were compared, based on the four compass directions, it was shown that both the cassava green spider mite and its predators dispersed predominantly in the direction of east and west i.e. the panels placed on these directions had the highest number of weekly catch during sampling period. This table also confirmed that the period of maximum dispersal occurred during the 4th to 6th weeks of the sampling period. Besides, significantly higher number of I.degenerans were caught emmigrating from the cassava plot during the 4th to 8th weeks of sampling.

Mean number of M. tanajoa and its predator N. teke during their outward dispersal from the cassava plot at MPFS is given in table 10.4. Similarly, it is indicated by this table that in the screen houses where N. teke was released, the mite densities on the foliage and panels increased to peaks during the fourth week simultanously. The peak density of the mites on the panels occurred the same week with that on the foliage (Table 10.4). The density of mites on the foliage was related to those on the panels by Y = 14.68 + 0.63x (SE = $\pm$ 0.17). This relationship was significant with b = 0.63, df = 7, at $P < 0.018$.

The mean number of N. teke trapped on the panels was related to the density of N. teke on the foliage by the formulat Y = 0.7 + 0.65x (SE = $\pm$ 0.09). The regression coefficient, (b = 0.65) was significant at 5% level of probability df = 7. This indicated that the dispersal of N. teke was density dependent.

Movement of N. teke and its prey M. tanajoa outwards of the screen house to the four compass directions is presented in table 10.5. This table indicated that both M. tanajoa and N. teke moved towards the east and west more than they did towards either the north or south. These movements or dispersal were significantly different during the fourth and fifth weeks from those occurring at the beginning of

dispersal for M. tanajoa and N. teke respectively ($F = 4.88$, df = 7, 14 and DMRT, df = 14, ($P < 0.05$).

10.4. DISCUSSION

The results obtained in this study on the dispersal within the plot indicated that emigration or dispersal of the predators in the absence of the prey occurred from the area or plant with high density to areas of low predator density. Takafuji (1977) attributed this dispersal to increase in hunger level of the predators. The redistribution of the predators from the point of release to other plant shoots showed that N. teke redistributed itself sparsely and moved faster than I. degenerans which dispersed slowly and tended to aggregate on the shoots as indicated by table 10.1. Although N. teke dispersed faster and further than I. degenerans, their depsersal was density dependent (i.e. density of the predators) as proved positively significant value of by regression coefficient. Bernstein (1984) proved that an increase in predators' density while keeping the number of prey nearly constant, produced steady increase in predator emigration. Sabelis (1981) showed the dependence of M. occidentalis emigration from prey colonies on its own density by performing an experiment without replacement of the prey. But, he performed it at high density of prey. Fernando and Hassell (1980) studied changes in emigration rate of P. persimilis females as a

function of their own density. They found that under experimental condition, the proportion leaving increased with their density.

The predator-prey systems formed by tetranychids and phytoseiids are systems which are unstable, discontinous and transient. It has been shown, theoretically, that the stability of these systems is increased among other phenomena by behavioural responses leading to aggregation of prey and predators (Hassell and May 1973, 1974; May 1978, Beddington et al, 1978); the avoidance of the predators by the prey (Sih, 1979) and increase in time spent by the predators on transit between the patches of prey colonies (Hassell and May, 1974; Murdoch and Oaten, 1975; Murdoch, 1977). It is therefore postulated that these three factors contributed to the level of dispersal attained by I. degenerans and N. teke. Besides phytoseiids have been known to walk much more rapidly than their prey (Bernstain, 1984). Johnson and Croft (1979, 1981) reported that they covered distances upto hundreds of meters in a generation.

During the assessment of aerial dispersal of M. tanajoa in relation to the dispersal of N. teke and I. degenerans the population density of M. tanajoa increased and then declined to a low density. There were various factors which contributed to the observed increase to a peak density of 399.07 mites/shoot which was followed by gradual decline of

mite density. First, the mite density might have increased due to the usual high numerical response of the tetranychids when they colonized a favourable host plant. It has been reported that M. tanajoa's intrinsic rate of increase, r_m was found to be highest on young leaves of young plants and lowest on older leaves of older plants (see chapter 12). Yaninek et al, (1986), reported similar findings. Therefore, the population growth rate declined when the plants began to shed the leaves due to damage as a result of the high mite density and plant age. The mites moved from an aging or exhausted resource to some new fresh resource (Mitchell, 1970).

Secondly, the observed decline in the mite population density could have been probably, due to emigration or dispersal to find new fresh resource. It was evident that most of the young stages were concentrated on first five leaves and there was an apparent upward migration to the upper young leaves. Emigration of T. urticae another tetranychid, response to host plant condition has been observed by Fleschner et al (1956) and Hussey and Parr (1963). But, Bernstain (1984) postulated that the injured parts of the leaf had some biochemical changes due to injury inflicted by the mites and that these caused the mites to diperse from the plants. Such biochemical changes have been found in this study (see chapter 12). Therefore, the rapid numerical increase which was observed resulted into

subsequent over exploitation of the host plant. Subsequently, aerial dispersal was initiated. The pattern of emigration or dispersal was very similar to the one observed by Charles and White (1988) with T. urticae from raspberry garden in New Zealand. M. tanajoa increased its emigration rate as shown by the numbers trapped on the panels. Bernstain (1984) suggested that mites would increase their emigration rates when density of the predators was high.

M. tanajoa dispersed aerially by spinning itself from the edge of the leaf on silken thread before being carried away by a light gentle breeze (Per. observ.). This observation was confirmed by Yaninek and Herren (1988). Hoelscher (1967) suggested that this passive dispersal increased their chances of founding a new colony. He established that passive dispersal was a function of the number of dispersers which decreased rapidly within the source field.

Fleschner et al (1956) and Kennedy and Smitly (1985) confirmed that most mits move between plants within a field by dispersing earially. Boyle (1957) and Nyiira (1972) reported that M. tanajoa spread in the direction of the prevailing winds although Fleschner et al (1956) and Hoelscher (1967) argued that mites can disperse in directions other than that of the prevailing winds.

However,the frequency and density of the mites trapped on the panels agreed with the findings of Nyiira (1972) that M. tanajoa dispersed in the direction of the prevailing winds. At MPFS the prevailing winds moved from west to east in the evenings and in the opposite direction (i.e. east to west) in the mornings. Thus, this mite spread from Uganda into Kenya near Busia and Siaya districts by 1973, was predominantly, through the north-east winds from that country (Nyiira,1972). Therefore, this study has elucidated the mechanism and direction of dispersal and transport of M. tanajoa and that the dominant dispersers were females which sought to gain access to new resources which would increase the chances for survival of their progeny. This propensity for young mated females to disperse is an adaptation found among mites for transient and spatially variable habitats.

However, it was essential that the predator of M. tanajoa should disperse even better and faster than their prey. In this study, it has been shown that the two phytoseiid predators, I. degenerans and N. teke dispersed within the plants and between plants within the cassava plot. These two predators dispersed differently in that N. teke dispersed much faster than I. degenerans. I. degenerans aggregated on the shoots, while N. teke was spersely distributed among the shoots. These attributes enabled each predator to exploit the prey population differently. Thus, I. degenerans over-exploited one patch

for too long while other patches increased in density. This phenomenon explained why the mite population density did not decrease immediately after predator releases. Probably, after this predator had spread evenly, it was then that the mite density began to show a definate decline.

On the contrary, N. teke spread itself spersely all over and thereby exerted immediate impact on the prey population. But, since it did not stay on one patch the mite population could recover easily. Nevertheless, when the predator was thinly dispersed their impact in suppressing the mite population was delayed. This resulted in a delayed density depended effect, hence delayed reduction in the prey density. Thus, this predator produced a prey-predator system with characteristics of delayed density dependent mortality factors and oscillations such as those observed by Nachman (1981). The resultant cycles of the prey and predators were more-or-less out of phase forming asynchronous oscillations.

The results indicated that both N. teke and I. degenerans dispersed aerially as indicated by those trapped on the panels. Their trend of dispersal was similar to that of their prey i.e. few dispersants were trapped during low predator density on the foliage and higher numbers were trapped when the density on the foliage was high.

Regression coefficient was significant which indicated that this dispersal was density dependent.

It was also found that more N. teke and I. degenerans were trapped on the east and west campass direction traps. This indicated that their dispersal might also be directional with the prevailing winds to the east and west. Apparently, these phytoseiids have adopted aerial movements as long distance dispersal mechanism. Similar findings have been observed and reported by other workers (Stabler 1913; Fleschner et al 1956; Hoelscher 1967; Johnson and Croft 1976, 1981; Mitchell, 1970; Bradenburg and Kennedy, 1982; Hoy et al, 1985).

Therefore, this study has revealed that these local phytoseiid predators dispersed reasonably well both within the plot so as to exploit their prey population. Besides this has shown that they could diperse aerially to cover long distances in search of new habitats where their prey populations have established themselves. Therefore, they can, probably, be released with the confidence that they would disperse and establish themselves among the cassava green spider mites in the field. It is postulated that for better results regular augmentation releases may be required to compensate for the high mortality during heavy rains.

Table 10.1 Dispersal capacity of N. teke and I. degenerans within the plot (6 x 6m^2)

Phytoseiid Predators

Sampling Day	I. degenerans (+ SE) Redistribution rate (X̄mite/shoot)	Dispersal rate (X̄mite distance)	Dispersal percent (Dispersal) %	Retaintion in plot (X̄mite/plot)	N. teke (+ SE) Redistibution rate X̄mite	Dispersal rate (X̄mite distance)	Dispersal percent (Dispersal) %	Retaintion in plot (X̄mite/plot)
1.	8.18±0.48	14.13±0.70	3.68±0.31	240.00±0.31	3.08±0.18	36.61±0.57	7.00±0.33	35.50±0.71
2.	9.04±0.22	16.04±0.50	4.75±0.26	207.00±0.45	2.37±0.31	50.39±0.76	8.20±0.62	30.00±0.53
3.	6.04±0.22	22.21±0.11	4.62±0.15	160.00±0.57	2.60±0.37	42.58±0.42	8.33±0.31	29.50±0.30
4.	4.77±0.29	26.97±0.92	5.58±0.71	156.00±0.17	2.17±0.16	52.46±0.89	9.83±0.35	22.33±0.37
5.	8.78±0.90	20.29±0.37	4.49±0.22	165.00±0.20	1.92±0.13	57.51±0.29	11.38±0.21	20.34±0.52
6.	11.94±0.29	16.61±0.62	3.48±0.16	188.00±0.80	1.45±0.20	50.69±0.60	13.38±0.43	15.00±0.61
7.	12.37±0.32	15.85±0.73	3.18±0.37	195.00±0.29	1.12±0.41	60.00±0.24	14.89±0.21	13.27±0.42

Table 10.2 Mean number densities of M. tanajoa and its predator I.degenerans on the panels and foliage of cassava during their outward dispersal from the cassava plot

Sampling dates	M. tanajoa on foliage (±SE)	M. tanajoa on panel (±SE)	I. degenerans on foliage (±SE)	I. degenerans on panel (±SE)
12/8/88	120.20±0.11 e	8.00±0.31 e	22.27±0.11 b	1.33±0.10 c
19/8/88	193.87±0.21 d	9.00±0.33de	22.67±0.20 b	5.67±0.21 b
26/8/88	265.33±0.87 c	14.00±0.13ede	44.80±0.30 ab	12.00±0.37a
2/9/88	399.07±0.11 a	34.00±1.20 a	36.20±1.10 ab	11.00±0.11 a
9/9/88	337.53±0.67 b	35.67±0.11 a	55.53±0.13 a	15.00±0.13 a
16/9/88	248.07±0.33 c	25.63±0.31 b	46.60±0.20 ab	15.00±0.17 a
23/9/88	174.80±1.33 d	19.33±0.40 bc	35.40±1.32 ab	14.00±0.11 a
30/9/88	118.87±1.67 e	17.33±0.33 bcd	25.67±0.87 b	11.33±0.20 a
C.V. (%)	0.53	21.76	10.02	19.02

Means in the same column followed by the same letter are not significantly different ($P < 0.05$, using Duncan's multiple range test, df = 14).

Table 10.3 Movement of M. tanajoa and I. degenerans outward of the screen house to the four compass directions at MPFS

Sampling Dates	Mean no, of CGM trapped on the panels North	South	East	West	Mean No. of I. degenerans trapped on the panels North	South	East	West
12/8/88	1.00±0.33 d	1.67±0.33e	2.67±0.10d	2.67±0.12d	0.00±0.00c	0.33±0.11	0.67±0.17e	0.33±0.11e
19/8/99	0.67±0.10d	2.33±0.55d	3.00±0.33d	3.00±0.33d	0.67±0.11c	1.33±0.17be	2.00±0.22b	1.67±0.13d
26/8/88	3.33±0.33bed	3.00±0.21cd	4.33±0.67cd	3.33±0.17d	3.00±0.13a	2.00±0.21ab	4.00±0.11a	3.00±0.27c
2/9/88	5.33±0.67ab	9.33±0.99a	10.33±0.21a	9.00±0.21ab	1.00±0.12be	2.33±0.10ab	4.67±0.33a	3.00±0.14c
9/9/88	8.00±1.00a	7.67±0.67ab	10.33±0.33a	9.67±0.18a	3.33±0.31a	3.00±0.12a	4.33±0.33a	4.67±0.17a
16/9/88	5.00±0.33abc	5.33±0.17bc	7.67±0.14b	7.00±0.31bc	2.33±0.67ab	2.67±0.31a	4.67±0.33a	4.33±0.11ab
23/9/88	3.00±0.10bed	4.33±0.18cd	5.67±0.11bc	6.00±0.35b	3.00±0.31a	3.00±0.14a	4.67±0.22a	3.33±0.12bc
30/9/88	2.00±0.01cd	3.67±0.31cd	6.00±0.23bc	5.67±0.67c	1.33±0.11bc	3.00±0.40a	3.67±0.66a	3.33±0.33bc
C.V.%	44.18	26.46	18.02	20.29	35.96	27.06	22.27	21.51

Means in the same column followed by the same letter are not significantly different (P<0.05) (using Duncan's multiple range test, df = 14).

Table 10.4 Mean number of M. tanajoa and its predator N. teke during outward dispersal from the plot

Sampling dates	M. tanajoa on the foliage ±SE	M. tanajoa on panels ±SE	N. teke on foliagge ±SE	N. teke on the panel ±SE
12/8/88	63.4±2.81 bc	10.00±0.10 d	9.27±1.20ab	0.00±0.00b
19/8/88	77.8±2.24 b	12.33±0.21 d	12.67±0.13a	0.33±0.11b
26/8/88	84.4±1.48 a	19.34±1.10 c	15.00±0.35a	1.67±0.67a
2/9/88	95.7±1.27 a	33.33±0.90 a	16.67±0.67a	2.67±0.33a
9/9/88	74.3±0.88 b	32.33±0.95 a	14.33±0.33a	2.67±0.10a
16/9/88	52.6±1.44 c	26.00±0.65 b	10.67±0.65a	1.33±0.67a
23/9/88	48.7±2.11 c	21.67±0.75 bc	8.67±0.88ab	0.00±0.00b
30/9/88	33.3±1.30 d	17.00±0.33 c	6.00±0.33b	0.00±0.00b
C.V.%	38.46	44.18	27.32	22.58

Means in the same column followed by the same letter are not significantly different($P < 0.05$) (using Duncans multiple range test , df = 14).

Table 10.5 Movement of N. teke and its prey M. tanajoa outwards of the screen house trapped on the panels at MPFS to the four compass directions.

Sampling Dates	M. tanajoa				N. teke			
	North	South	East	West	North	South	East	West
12/8/88	2.00±0.11 c	2.33±0.35 d	3.33±0.31 f	2.33±0.44 d	0.00±0.00b	0.00±0.00.b	0.00±0.00d	0.00±0.00b
19/8/88	2.33±0.31 c	2.33±0.13 d	4.67±0.11 f	3.00±0.07 d	0.00±0.00b	0.00±0.00.b	0.33±0.10c	0.00±0.00b
26/8/88	4.67±0.12 ab	3.67±0.14 cd	6.33±0.38 e	4.67±0.12 c	0.33±0.10ab	0.00±0.00.b	0.67±0.13ab	0.67±0.11a
2/9/88	6.00±0.30 a	7.33±0.33 a	12.33±0.09 a	7.67±0.32 b	0.67±0.13 a	0.33±0.01.ab	1.33±0.15 a	0.33±0.00ab
9/9/88	5.67±0.22 a	7.00±0.21 a	10.33±0.03 b	9.33±0.11 a	0.33±0.10 a	0.67±0.00.a	1.00±0.33 a	0.67±0.10a
16/9/88	3.33±0.41 b	6.33±0.15 b	8.67±0.14 c	7.67±0.25 b	0.00±0.00 b	0.33±0.00.ab	0.67±0.10ab	0.33±0.03ab
23/9/88	3.00±0.27 b	4.67±0.18 c	7.67±0.08 cd	6.33±0.21 b	0.00±0.00 b	0.00±0.00.b	0.00±0.00 d	0.00±0.00b
30/9/88	1.33±0.38 d	4.00±0.34 c	7.00±0.45 d	4.67±0.42 c	0.00±0.00 b	0.00±0.00 b	0.00±0.00 d	0.00±0.00b

Means in the same column followed by the same letter are not significantly different ($P<0.05$) (using Duncans Multiple Range Test, df = 14).

11.0 EFFECT OF RAINFALL ON M. TANAJOA AND ITS TWO LOCAL PHYTOSEIID PREDATORS

11.1 INTRODUCTION

Rainfall has been implicated as one of the major sources of mortality of the cassava green spider mite and its predators. This claim has been made that the torrential tropical rainfall has impeded the establishment of exotic predators introduced from the Neotropics which is the origin of M. tanajoa. (Akinlosotu, 1982; Byrne et al, 1983; Ndonga et al, 1986; Nyiira 1975, 1977; Yaninek and Animashaun 1987; Yaninek et al, 1986; Markham, Pers. com.). However, there is no quantitative data available on the actual impact of this important climatic factor on the population of this mite. Therefore, this experiment was designed to quantify the effect of rainfall intensities on the populations of stages of M. tanajoa and its two locally occurring predators I. degenerans and N. teke

11.2 MATERIALS AND METHODS

Sixteen potted plants of "Kibandameno" cassava variety which had been planted in perforated 10-litre plastic pails were used. The plants had taken six weeks to sprout and attain growth whereby they had average of 20 leaves per plant. Then, the 16 plants were artificially infested with

40 mated and ovipositing females of M. tanajoa to provide approximately uniform population per plant. These plants were left for two weeks during which the mite population was allowed to develop for one generation.

On the fifteenth day, the plants were divided randomly into four categories with four replicates each. Then, the various stages of the mite on the leaves and apical bud were counted per plant. These developmental stages and adults of the mites were determined and counted using binocular microscope ('Wild 5A') (120 x magnification) by placing the pot in which the plant was growing gently on its side and flexing the leaves under the microscope. A record was taken of the eggs, larvae, nymphs, adults, males and females on each plant of each category

. Then three rainfall intensities were similated using three 20-litre tin-pails whose bottoms were perforated with holes of approximately 1.0, 1.5 and 2.0mm diameter at 4.0cm apart to simulate light (gentle), moderate (medium) and heavy rainfall intensities respectively. Each pail was suspended on a quantriapod of steel stand which was placed across car inspection pit (Diag.3). The distance from the bottom of the pail to the plant was approximately 4 meters. These rainfall "intensities" were assigned to each category of four plants i.e. replicated four times and one set of four plants was left as control.

Then, the infested plant was placed at the bottom of the inspection pit directly under the suspended pail. Initially, water was poured into the pail using another pail and the perforated pail was maintained full by using a hoose pipe (this was done to maintain the same pressure throughout the 15 minutes. for which the "rain" fell on each plant). Then the plant was removed and left to dry from the wetness. After each treatment was completed a conventional rainguage was placed under the pail in the inspection pit and the exercise was repeated i.e. the amount of rainfall was collected in the rainguage and the total amount was recorded for each treatment.

Then, finally, densities of the stages remaining on the same plants were determined in a similar manner as those of the initial counts. Besides, close observations were made on the stems and leaf buds for any dislodged stages and remnant stages in the buds.

In another experiment, 20 pairs of the predators namely, I. degenerans and N. teke (ex-Mbita strain) were each released onto 16 plants upon which 50 mated and ovipositing females of M. tanajoa had been artificially introduced two weeks earlier. M. tanajoa was released earlier to serve as food source for the predators. These predators were left for 38 days to establish themselves for three generations on those plants.

On the 19th day, the 16 plants were divided into four categories of four replicates each. Then, the stages of each predator were counted by using the same binocular microscope (X120 magnification). The stages of the predators were counted and categorised into eggs, nymphs and adults. Then, the plants together with the predators were subjected to the same treatments (i.e. three raifall intensities and control) as those used on the M. tanajoa populations earlier.

The final densities of the stages of the predators were determined after the plants had dried from wetness in a similar manner to that of the initial densities.

11.3 RESULTS

11.3.1. On M. tanajoa

Effect of simulated 'rainfal intensities' on various stages of M. tanajoa is presented in figure 11.1. This figure showed that there were significant reductions in the mean number of the various stages of M. tanajoa after treatment with the three different rainfall intensities ($F = 4.58$, $df = 3,9$, $P < 0.05$).

Moreover, the mean number of eggs (778.10 eggs/plant) on the plants used as control were significantly higher than the mean number of eggs on the plants treated with any of the three 'rainfall intensities' ($F = 6.14$, $df = 3,6$, $P < 0.05$ and DMRT, $df = 9$, $P < 0.01$). Nevertheless, the number of eggs on the plants treated with 'light rain' (295 eggs/plant) was significantly higher than those on either 'moderate' (257.25 eggs/plant) or 'heavy rainfall' (161.75 eggs/plant) (DMRT, $df = 9$, $P < 0.05$). Besides, the mean number of eggs on the plants treated with 'heavy rainfall' 161.75 eggs/plant) was significatly lower than that on the plants treated with 'moderate rainfall' at 5% level of probability (DMRT, $df = 9$, $P < 0.05$). Thus, 'light',' moderate'and 'heavy rainfall' intensities reduced the eggs stage by 58.49, 54.26 and 67.79% respectively whereas those on control plants increased by 33.28% (Table 11.2).

Further, the mean number of larvae on the plants which were treated as control (60.05 larvae/plant) was significatly higher than those on the plants which were treated with any of the three rainfall intensities (DMRT, $df = 9$, $P < 0.05$). But the mean number of larvae on the plants which were treated with 'light' and 'moderate' rainfall intensities (21.05 and 17.15 larvae/plant) were not significantly different at same level of probability. However, the mean number of larvae (2.30) on plants treated with 'heavy' rainfall intensity was significantly lower than

those on either plants treated with 'light' or 'moderate'rainfall intensities (DMRT, df = 9, $P < 0.05$). Therefore, the reduction of the larval stage by 'light',' moderate' and 'heavy' rainfall intensities were 49.70, 41.32 and 87.50%. whereas the larvae on plants used as control increased by 14.16%.

Mean number of nymphs on plants which were treated with 'light', rainfall intensity (87.55 nymphs/plant) was significantly higher than those on plants treated with either 'moderate' or 'heavy' rainfall intensities (55.45 and 31.55 nymphs/plant respectively) (DMRT, df = 9) at 5% level of probability. Nevertheless, mean number of nymphs on plants treated with 'heavy' rainfall intensity (31.55 nymphs/plant) was significantly lower than that on the plants treated with 'moderate' rainfall (DMRT, df = 9, $P < 0.05$). Thus, the percentage mortality reduction of this stage by 'light', 'moderate' and 'heavy' rainfall intensities were 12.89, 58.94 and 59.60% while the mean number of nymphs on control plants increased by 4.06% (Fig.11.2).

Moroever, the mean number of M. tanajoa adults on plants treated with 'light' and 'moderate' rainfall (40.10 and 38,25 adults/plant) were not significantly different (DMRT, df = 9, $P < 0.05$). Whereas the mean number of adults on plants treated with 'heavy' rainfall intensity (26.80

adults/plant) was significantly lower than those on plants treated with either 'light'; or 'moderate' rainfall intensity at (DMRT, df = 9) 5% level of probability, those on plants which were not treated were significantly higher than all those on treated plants at the same level of probability. The adults suffered percentage mortality due to 'light', 'moderate' and 'heavy' rainfall intensities by 57.02,, 50.67 and 65.61% whereas those on plants which were used as control increased by 3.77% (Fig.11.2).

Further, the mean number of M. tanajoa males on plants treated with 'light' and 'moderate' rainfall intensities (11,40 and 10.55 males/plant respectively) were not significantly different (DMRT, df = 9, $P < 0.05$). But those males on plant which were treated with 'heavy' rainfall intensity (2.10 males/plant) were not significantly lower than those on plants treated with 'light' and 'moderate' rainfall intensities at the same level of probability. Therefore, 'light;, 'moderate' and 'heavy' rainfall intensities reduced males by 40.63, 39.89 and 88.20% respectively whereas the mean number of males on untreated plants increased by 14.71% (Fig.11.2).

Moreover, the mean number of M. tanajoa females on plants treated with 'moderate' and 'heavy' rainfall intensities (32.05 and 25.20 females/plant) were not significantly different although they were significantly

lower than those on the plant which were treated with 'light' rainfal intensity (DMRT, df = 9, P < 0.05) (Fig.11.2). Thus, 'light' 'moderate' and 'heavy' rainfall intensities caused female apparent mortalities of 37.76, 43.83 and 58.10% whereas those on the untreated plants increased by 29.76% (Fig.11.2).

11.3.2. ON THE PHYTOSEIID PREDATORS

Effect of the three simulated rainfall intensities on the two phytoseiids namely I. degenerans and N. teke is presented in table 11.1. This table showed that mean number of eggs of I. degenerans found on plants which were treated by the three levels of rainfall intensities were zero whereas the plants which were used as control had 13.25 eggs and it was significantly different from the treated ones (DMRT, df = 9) at 5% level of probability. This stage suffered 100% mortality as a result of any of the simulated rainfall intensities (Fig.11.3).

However, the nymphal stage of I. degenerans on all the treated plants were not significantly different (F = 2.31, df = 3,6, P < 0.05). But 'light', 'moderate' and 'heavy'rainfall intensities reduced their populations by 89.47, 89.65 and 95.92% respectively while those on the untreated plants increased by 22, 22% (Fig.11.3).

Moreover, mean number of adults of I. degenerans on the plants treated with any of the three rainfall intensities was significantly lower than the number of adults on untreated plants (29.00 adults/plant) (DMRT, df = 6, $P < 0.05$). Nevertheless, mean number of adults of I. degenerans on plants which were treated with 'heavy' rainfall intensity (0.50 adults/plants) was significantly lower than those on the plants which were treated with 'light' and 'moderate' rainfall intensities (7.50 and 8.00 adults/plants respectively) (DMRT, df = 6, $P < 0.05$). Percentage mortality of adult I. degenerans due to the 'light'' moderate' and 'heavy' similated rainfall intensities were 68.42, 71.17, 98.06% respectively. (Fig.11.3).

Effect of three simulated ranfall intensities on N. teke is presented in figure 11.3. It is indicated in this figure that eggs and nymphs of this predator were considerably reduced by all the three simulated rainfall intensities. However, there were no significant differences among the number of either eggs or nymphs on the plants which were treated with the three different simulated rainfull intensities at 5% level of probability ($F = 2.22$, df = 3,6, $P < 0.05$). Egg stage suffered mortalities of 96.10, 95.83 and 93.91% whereas nymphs were reduced by 93.22, 92.54 and 95.71% due to 'light' 'moderate' and heavy rainfall intensities respectively. Nevertheless, the number

of eggs and larvae on the untreated plants increased by 22.22 and 7.04% respectively (Fig.11.3).

Moreover, mean number of the adult stage of N. teke on the treated plants were significantly lower than those on the plants which were not treated (32.50 adults/plant) (DMRT, df = 6, $P < 0.05$). However, the mean number of adults on the plants treated with 'light' rainfall intensity (18.50 adults/plant) was significantly higher than either those on plants treated with 'moderate' or 'heavy' rainfall intensities (11.50 or 7.25 adults/plant respectively). But the number of adults on plants treated with 'moderate' rainfall intensity was significantly higher than those on plants treated with heavy rainfall intensity (DMRT, df = 6, $P < 0.05$). The number of adults on plants treated with 'light', 'moderate' and 'heavy' simulated rainfall suffered mortalities of 32.11, 62.90 and 74.78% respectively whereas those on the untreated plants increased by 7.44% (Fig.11.3).

11.4 DISCUSSION

The results revealed that three simulated rainfall intensities reduced the various stages of M. tanajoa differently. The highest percentage mortality was caused by heavy rainfall intensity which indicated that during heavy downpour of rain all the stages of this mite suffered very high population reductions compared to that which occurred during light and gentle rains.

However, among the immature stages of M. tanajoa the results suggested that eggs suffered the highest apparent mortality. This stage was most vulnerable because it lacked organs of mobility. Whereas the other stages could move and hide underneath the leaves or hold tightly onto the leaf surface with their tarsi so that the impact of the rain drops does not dislodge them. But these results showed that over 50% of the egg stage of M. tanajoa was apparently dislodged by the impact of the rain drops or drowned by rain water.

Further observations had revealed that some eggs which were on the leaves and stems were burst and displaced onto the stems. These burst eggs embibed the water through the egg pore and swelled to size where they burst the egg membranes due to high osmotic pressure especially those which were freshly laid just before the treatment was

started. Ndonga (unpublished) had demostrated that 28% freshly laid eggs burst within the first 20 minutes when they were immersed in water whereas only 15% of one - day old eggs burst within the same period of immersion in water. Obviously, the chorionic membranes of the newly laid eggs had not hardened sufficiently to resist the osmotic pressure from causing the eggs to burst whereas those of the one-day old eggs had hardened and therefore, could resist osmotic pressure for a longer period, and therefore were just dislodged from their original positions where they had been laid.

Moreover, some dead larvae and adults were also found on the stems and undersides of the leaves of the cassava plants. Obviously, these larvae and adults were drowned by the run-off of 'rain'. These observations suggested that the mechanisms by which the simulated rainfall reduced the population of M. tanajoa was by either dislodging by its impact onto areas which were unfavourable for their survival or by drowing them. This high apparent mortality of the immature stages of this mite reduced the population size of the subsequent generations. Similar reductions in the population of this mite have been reported elsewhere (Leuschner, 1980; Munthali, 1986; Nyiira, 1977; Yaninek and Animashaun 1987).

However, these results of this experiment have shown that 'heavy' rainfall intensity caused higher mortality among the stages of this mite than 'light' and 'moderate' rainfall intensities. This high mortality was probably, due to the strong force of impact with which droplets of 'heavy' rainfall hit the leaves. Thereby, dislodging and drowning most of the stages of the mite population. Yaninek et al (1986) recognised that functional form of rainfall mortality was a dose-response curve which increased from zero to more than 50% at less than 5mm/hr then, levelled of to 75% between 10 and 60 mm/hr. Thus, heavy rainfall intensity caused high mortalities among stages of M. tanajoa whenever it occurred. However, Bellotti et al, (1977) argued that total precipitation influenced both distribution and quality of the cassava host plant which in turn influenced the intrinsic rates of the population increases of M. tanajoa. Therefore, rainfall mortality suppressed the superior growth rates of this species during the wet seasn. Besides, it has been found that M. tanajoa population growth rate was highest during the wet season especially on young leaves of young plants (Yaninek and Animashaun, 1987), the population expected from that growth rate was never realised because of the heavy rainfall which suppressed it.

Furthermore, although the 'heavy' rainfall intensity caused high mortality, a small percentage of each stage of the mite population remained as a residual population which could perpetuate the species soon after the mortality factor of rainfall was removed when the rainy season ended. Similar findings were reported by Munthali (1986) in Malawi. Therefore, this phenomenon, apparently, explained why the tropical torrential rains of Africa have not eradicated this pest from the African continent.

Besides, it had been observed that at the end of the wet season, there was a rapid population build-up due to the high population growth rates of this mite. Probably, influence of the host plant being lush and suitable enhanced the population growth rate of the residual population and thereby, causing a rapid population build-up and the restoration of the status of their population density. Thus, the rise in the population growth rate occurred because the parents fed on nutritious food source in the host plant (Wrensch and Young, 1976).

Similarly, the results of this study have shown that the phytoseiid predators suffered high mortalities just as the host mite did. But I. degenerans was very susceptible to the effects of rainfall especially the egg stage and this resulted to its eradication. The survivors of I. degenerans

were predominantly adults. Moreover, this observation partly explained why this predator tended to be distributed on the undersides of the lower leaves of the plant where it would be sheltered from rain and other hazards.

Although, N. teke also suffered very high mortalities, its small eggs stage residual population remained in the crevisees and underneath the leaves. Neverheless, the survivors were mostly adults. The adults survived the rainfall effects probably because they were more mobile and they could move and hide under the leaves or hold onto the leaf surfaces strongly so as to avoid being dislodged by the impact of the rain drops.

Moreover, high mortalitis among the immature stages of thse predators reduced the size of their population in the subsequent generations which would attack the M. tanajoa. Subsequently, population of M. tanajoa in the field would increase rapidly (Yaninek et al 1986). Besides, these phytoseiid predators have been shown to have lower population growth rates (chapter 5.3) which implied that the population of the mite would recover much faster compared with that of the predators. Hence, the failure of the predators to suppress the population of the mite in the field soon after the wet season. Nevertheless, Munthali (1986) found that if I. degenerans had sufficient period, it

could recover and suppress the population of M. tanajoa before an outbreak occurred.

Therefore, it was concluded that rainfall caused marked population decline of the population densities of both M. tanajoa and its phytoseiid predators through its impact and drowning. However, a residual population usually remained to perpetuate the species concerned. Subsequently, the torrential tropical rains have not erradicated this pest from our continent. Thus, the effect of heavy rainfall intensities accounted for the constant, and sharp population fluctuations particularly the sharp declines which were observed in the field.

Diag. 11.1

APPARATUS FOR RAINFALL SIMULATION

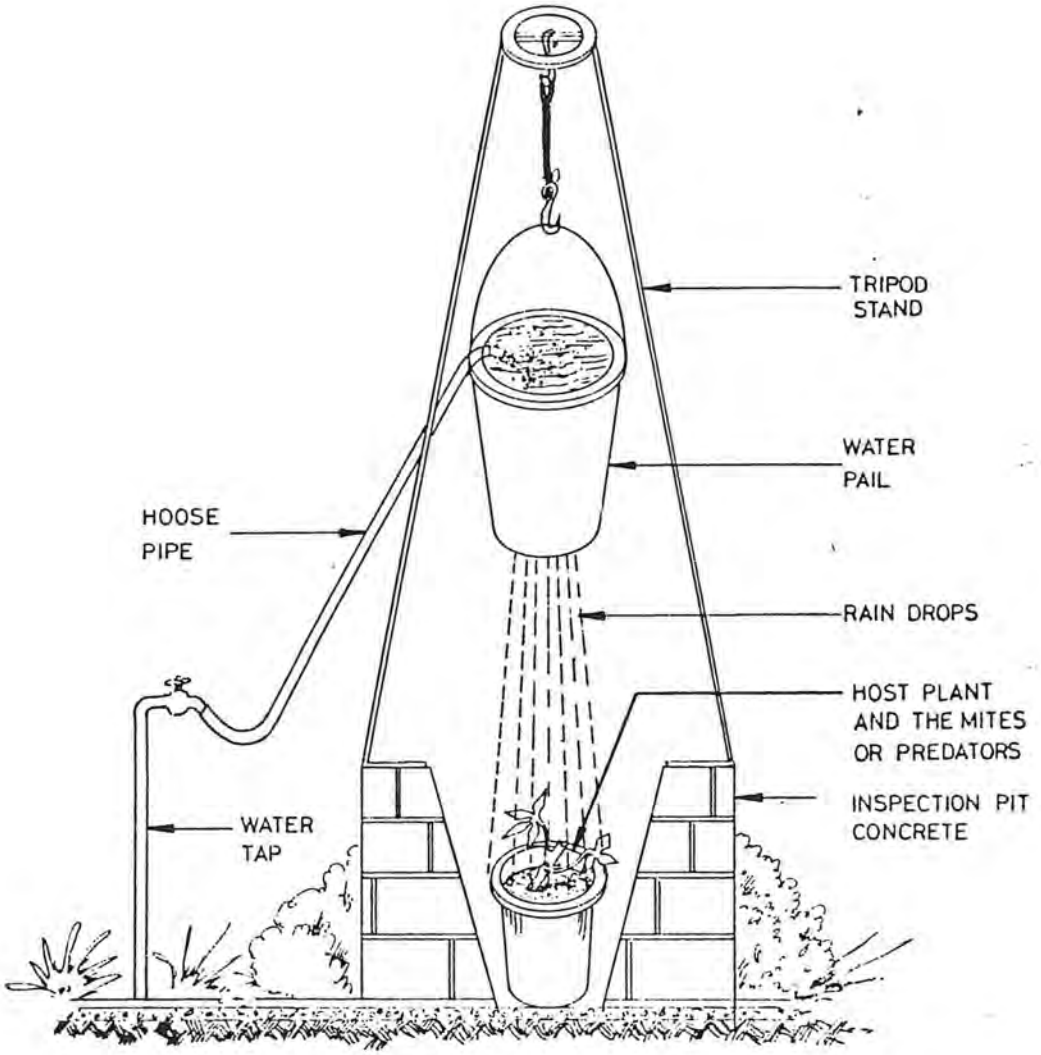


Fig. 11.1

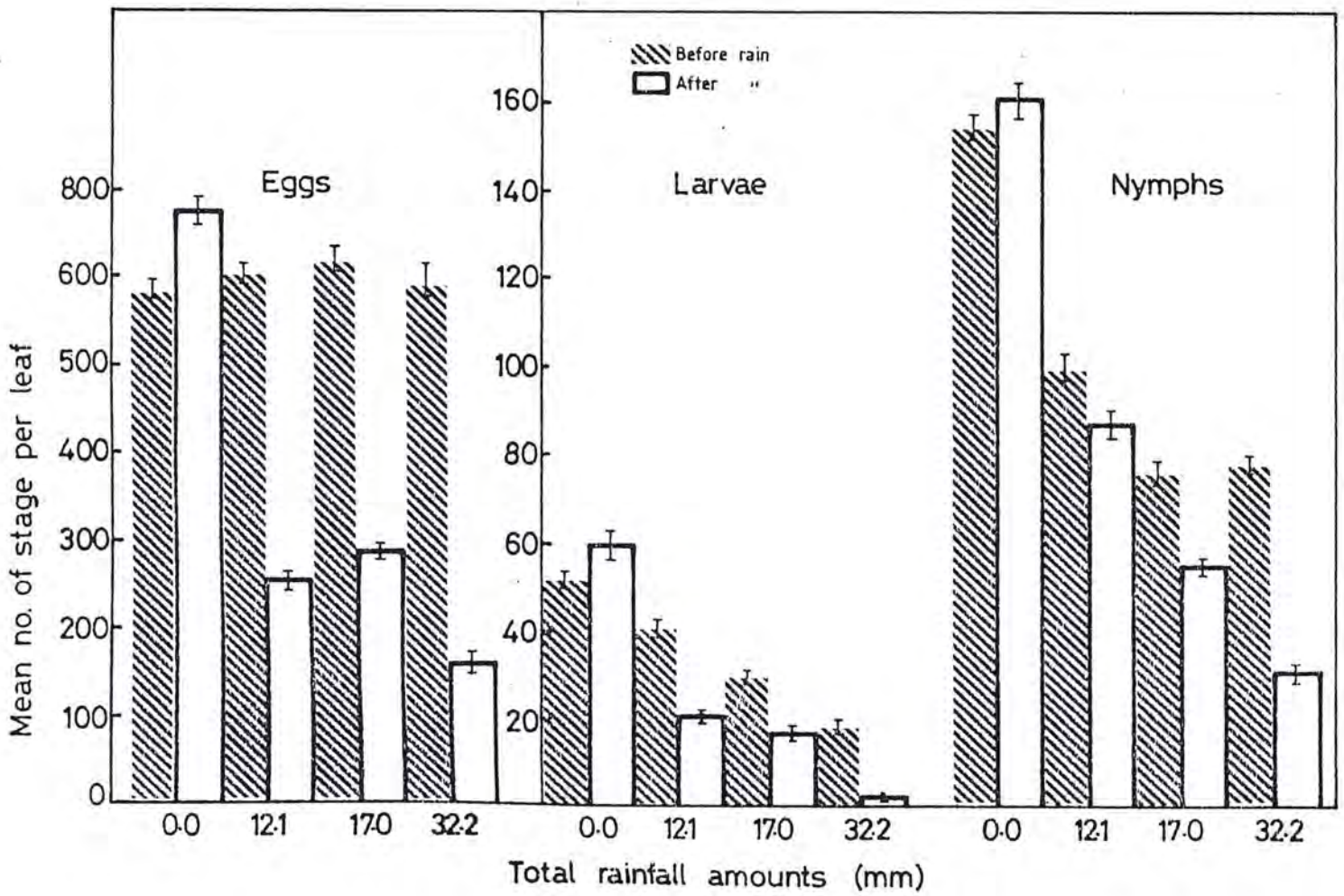

Before rain
After "
Eggs
Larvae
Nymphs
Mean no. of stage per leaf
800
600
500
400
300
200
100
0
160
140
120
100
80
60
40
20
0·0
12·1
17·0
32·2
Total rainfall amounts (mm)

Fig. 11.1 contd.

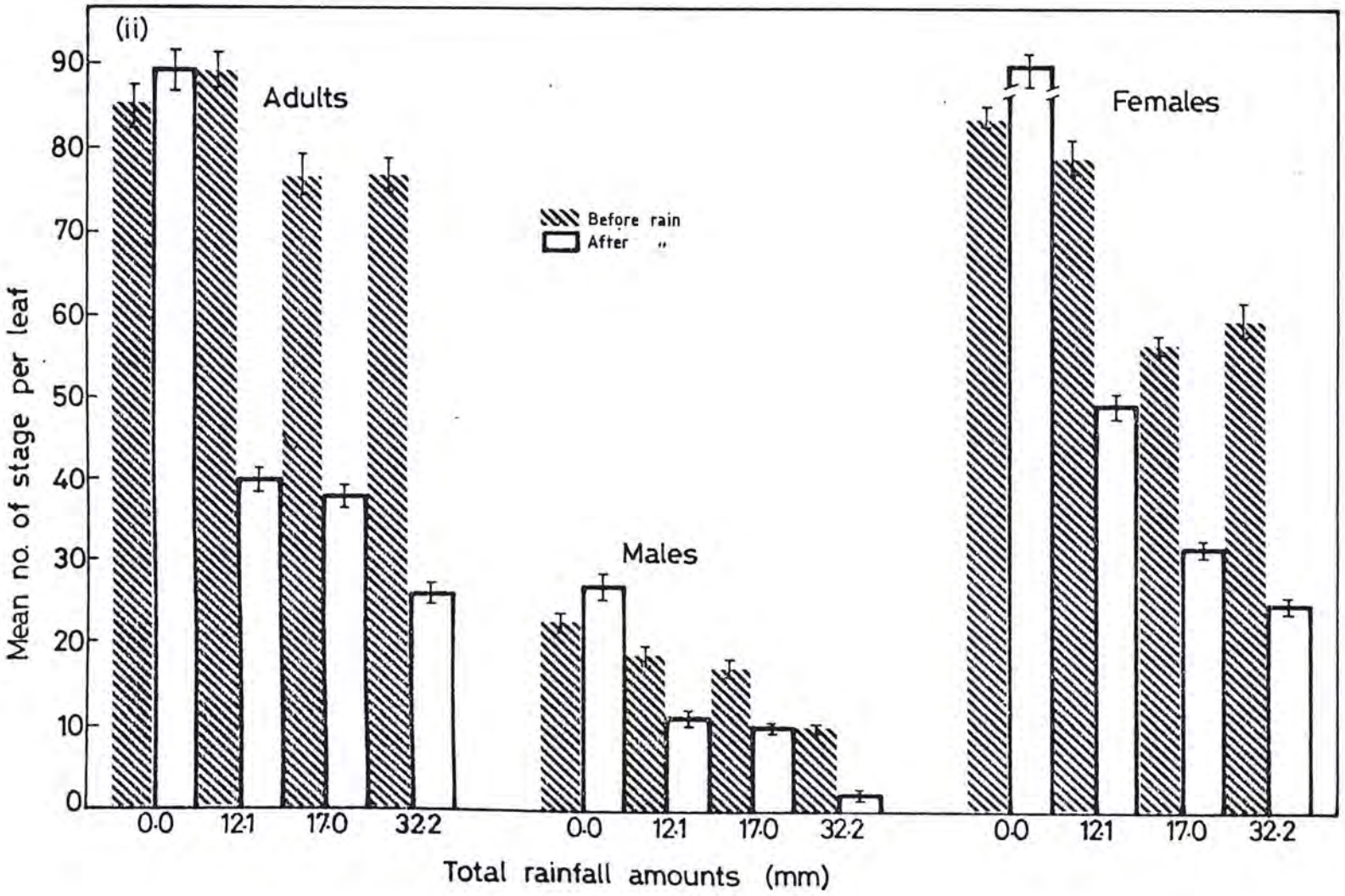


Figure 11.2 Percentage mortality of M. tanajoa stages subjected to simulated rainfall intensities.

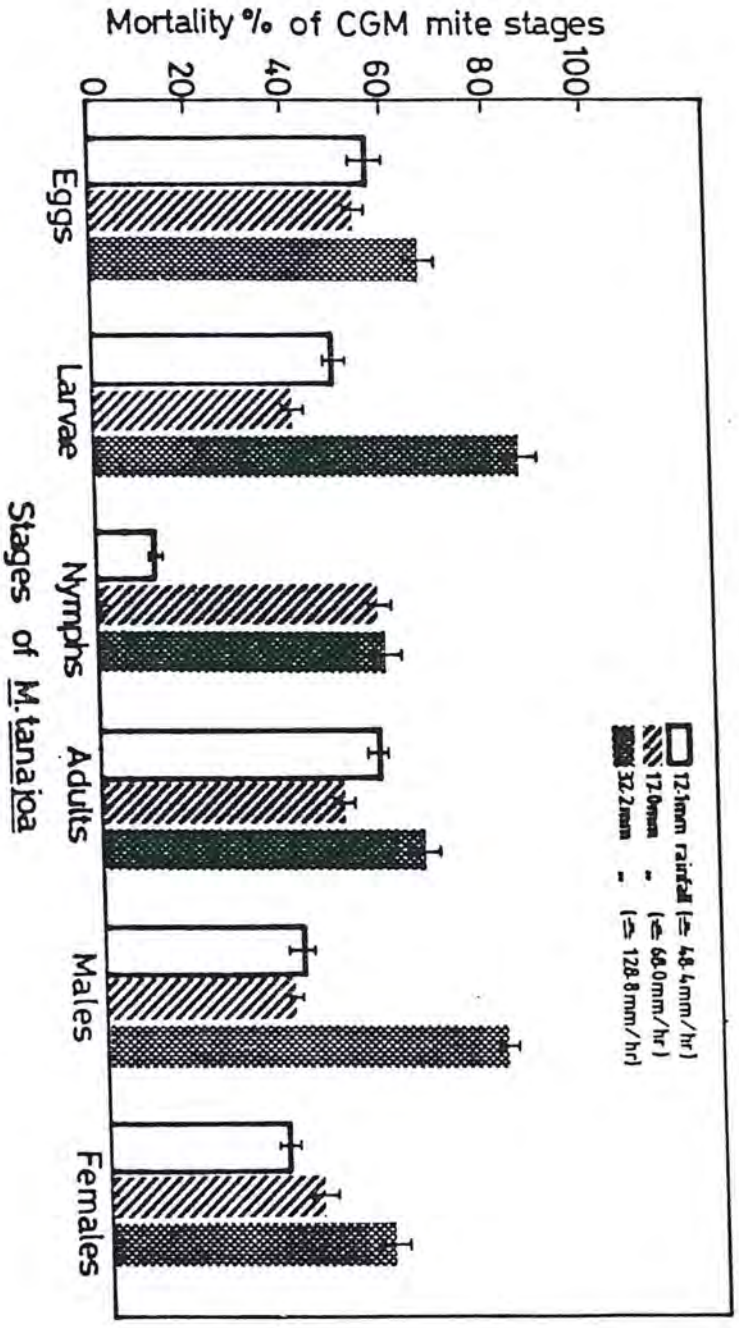

Mortality % of CGM mite stages
0
20
40
60
80
100
Eggs
Larvae
Nymphs
Adults
Males
Females
Stages of M. tanajoa
12.1mm rainfall (≥ 48.4mm/hr)
12.0mm (≤ 66.0mm/hr)
32.2mm (≥ 128.8mm/hr)

Fig. 11.2

Figure 11.3 Percentage mortality of the phytoseiid predators when subjected to simulated rainfall intensities. A is for *I. degenerans* and B, *N. teke.*

Fig. 11.3

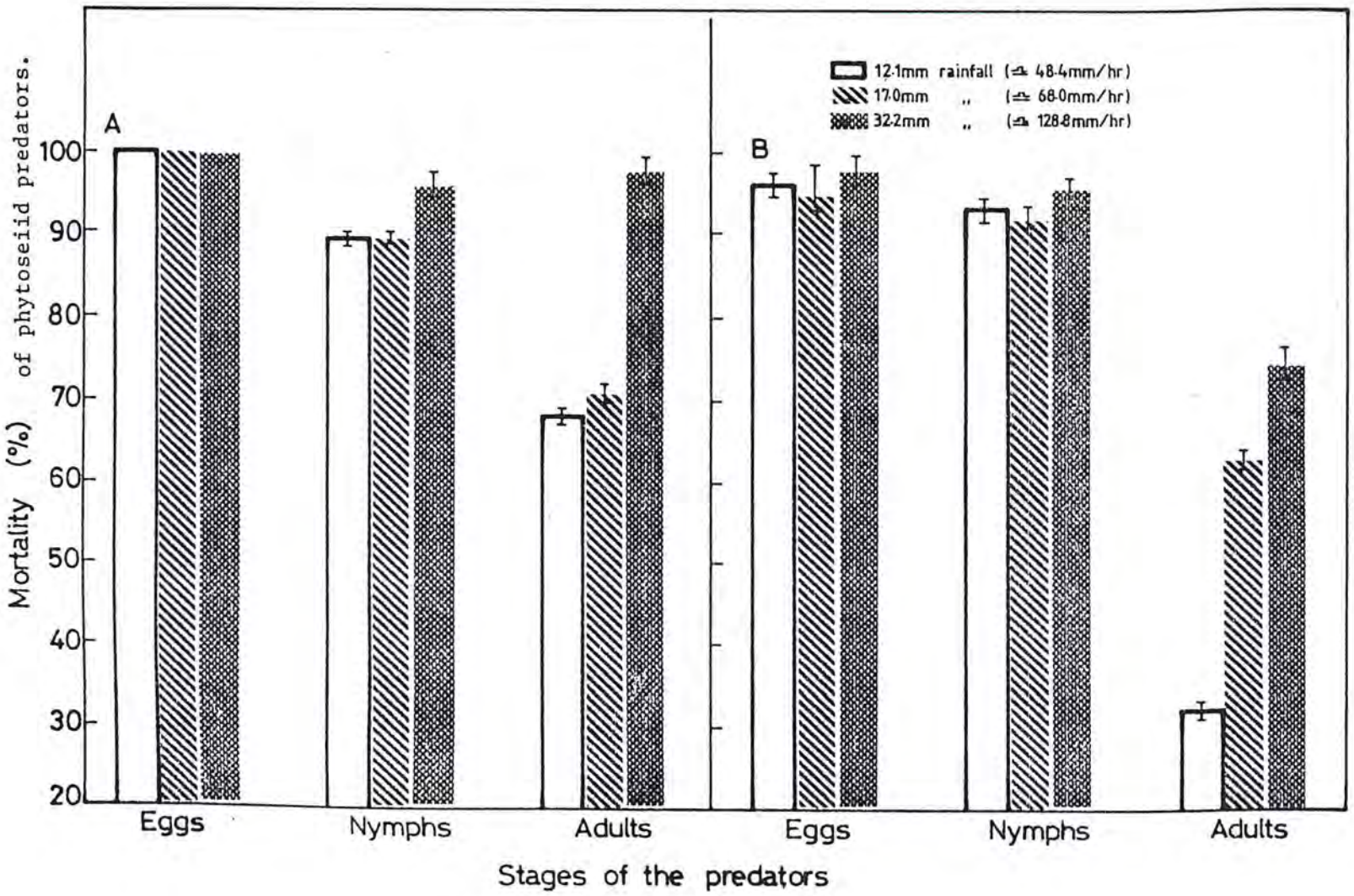

12·1mm rainfall (≙ 48·4mm/hr)
17·0mm ,, (≙ 68·0mm/hr)
32·2mm ,, (≙ 128·8mm/hr)
A
B
Mortality (%) of phytoseiid predators.
100
90
80
70
60
50
40
30
20
Eggs
Nymphs
Adults
Eggs
Nymphs
Adults
Stages of the predators

Table 11.1. Reduction of two phytoseiid predators I. degenerans and N. teke by varioús simulated rainfall intensities

Rainfall intensities (amount,mm)	I. degenerans			N. teke		
	eggs	nymphs	adults	eggs	nymphs	adults
Before rainfall						
Control (0.0)	10.50 a	9.00 a	26.25 a	20.25 ab	17.75 a	30.25 a
Light (12.1)	12.50 a	9.50 a	23.75 a	19.25 b	14.75 ab	27.25 a
Moderate (17.0)	14.25 a	7.25 ab	27.75 a	18.00 b	16.75 a	31.00 a
Heavy (32. 2)	10.75 a	12.25 a	25.75 a	23.00 a	17.50 a	28.75a
After rainfall						
Control (0.0)	13.25 a	11.00 a	29.00 a	24.75 a	19.00 a	32.50 a
Light (12.1)	0.00 b	1.00 b	7.50 b	0.75 c	1.00 c	18.50 b
Moderate (17.0)	0.00 b	0.75 b	8.00 b	0.75 c	1.25 c	11.50 c
Heavy (32.2)	0.00 b	0.50 b	0.50 c	0.25 c	0.75 c	7.25 c

Mean in the same column followed by the same alphabetical letter are not significantly different at $P < 0.05$, df=6 (Using Duncan's multiple range test).

Figures in brackets are total rainfall amounts (mm) in 15 minutes.

12. EFFECT OF POPULATION DENSITY OF M. TANAJOA ON ITS HOST PLANT

12.1. INTRODUCTION

In the course of monitoring the population density of M. tanajoa, it noticed that when the population density of this pest increased above a certain threshold level the host plant became defoliated. Since this defoliation occurred during the hot dry weather, it was not clear whether this phenomenon was due to the severe water stress which the plant was subjected to during the hot dry weather or the high pest density which extracted more nutrients from the leaves of the plant.

Besides, all the developmental stages and adults of this pest were mostly found on the lower surfaces of young leaves where they fed by piercing individual leaf cells with their stylet-like mouth parts and extracted the cell fluids. Symptoms of damage by this pest included chlorotic spotting of the leaves, shortened internodes and stunted leaf expansion or growth as mentioned earlier.

Similar observations have been made by other authors (Yaninek and Animashaun, 1986; Ndonga et al, 1986; Nyiira, 1973). Therefore, investigations were carried out to

ascertain the effect of population density of M. tanajoa on cassava plant.

12.2. MATERIALS AND METHODS

Cuttings of susceptible 'Kibandameno' cassava variety (25 cm. long) were planted in 15 - litre plastic pails filled with soil. The pails were placed in cages 1.5m x 1.5m x 2.0m (width x length x height) covered with fine netting cloth material. Then, they were left in direct sun under similar conditions to those in the field but they were being watered regularly at two days intervals until the plants attained average of 20 leaves each.

Then, forty laboratory reared ovipositing females of M. tanajoa were introduced onto leave number three of the shoot of each plant. These females were handled using a fine camel hair brush. Then, they were left for four weeks during which time the mite population increased by two generations.

Thereafter, the first five fully expanded leaves from the terminal shoot of five plants were sampled for counting both live and dead developmental stages and adults of the mite. Both dead and live developmental stages of this mite were counted using dissecting microscope ('Wild 5A'x 120 magnification). The leaves were examined by placing the pot

on its side and flexing the leaves under the microscope (to avoid plucking the leaves off the plants). Sex ratio was obtained by counting the two sexes separately from the same leaves.

Oviposition preference on young and mature leaves was assessed by counting the number of eggs on leaves numbers 3 and 8 of the same plant (counting leaf one from the first fully expanded leaf from the terminal shoot). These eggs were counted from five plants as replicates during each sampling occasion.

Furthermore, ten plants were used for the estimation of chlorosis by visual rating of 0 to 5 according to Hussey and Parr (1963). The same plants were concurrently assessed for the degree of defoliation percent by counting the number of young leaves dropped (i.e. leaf scars) as a percentage of the total number of leaves present (excluding scars of leaves which dropped from the lower portion of the plant due to old age). Sampling for the above parameters began when the plants were eight weeks old and it was continued for nine subsequent weeks at weekly intervals. Thereafter, frequent observations were made on the terminal and lateral buds and stem upto the time the plant had regenerated during the eleventh week.

Besides, 20 leaves of five months old 'Kibandameno' cassava variety, each of damaged (score of 4) and undamaged leaves, were collected for analysis of components of the damaged and undamaged leaves. These leaf samples were placed in polythene bags and sent to the National Agricultrual Research Laboratories of Kenya Agricultural Research Institute (KARI), Nairobi. The leaf samples were analysed for chlorophyll a and b, dry matter, calcium, potassium, sodium, nitrogen, zinc, manganese, crude protein and magnesium. The methods used for analysis were those recommended by Association of Official Analytical Chemists (AOAC) (1975). But the chlorophylls were extracted in 20 mls of 80% acetone/water (i.e 80:20 v/v). The extract was centrifuged and the clear extract decanted. The amounts of chlorophylls a and b were determined using spectrophotometer at selected wavelengths of 663 and 645 nm for the respective chlorophylls absorption.

12. 3 RESULTS

Population density of the various stages of M. tanajoa during the sampling period is presented in figure 12.1. This figure shows that populations of eggs and larvae increased gradually from the time when the mites were artificially introduced onto the plants. These two stages reached their peak densities of 673.5 and 103.3 eggs and

larvae respectively per leaf whereas the nymphs and adults reached their peak densities simultaneously during the seventh week of sampling.

Moreover, having reached their maximum densities, the eggs and larvae decreased gradually and significantly lower to 403.6 egg/leaf and 42.1 larvae per leaf from their maximum densities ($F=12.3$, $df=8,32$, $P< 0.01$). Population densities of nymphs also decreased sharply and significantly lower (092.6 nymphs/leaf) than their maximum density (DMRT, $df=32$, $P<0.05$) during the eighth and with weeks (DMRT, $df=32$, $P<0.05$). During the ninth and subsequent weeks the population densities of the various stages of the mite had decreased considerably to very low levels. The residual populations which were found only on the leaf buds and crevisees consisted of eggs (40.3 plant) larvae (10.0/plant), nymphs (52.3/plant) and adults (8.7/plant).

Percentage mortalities of the stages of M. tanajoa during the sampling period of infestation is presented in figure 12.2. It is shown by this figure that percentage mortalities among the different stages were significantly different ($F=12.3$, $df=8,32$, $P < 0.01$). Although during the first three weeks there were no significant mortalities among the stages of this mite (DMRT, $df=32$, $P<0.05$), during the sixth week the mortality of adults increased significantly from 31.2% to 82.0% during the seventh week

(DMRT, df=32, $P < 0.05$). But during the seventh and eighth weeks (82.0 and 88.3%) there were no significant difference in the adult mortality (DMRT, df=32 ,$P<0.05$). Besides during the ninth week adult mortality declined significantly from 88.3% to 5.5%. (DMRT, df=32,$P < 0.05$).

The juvenile stages of M. tanajoa, namely, eggs, larvae and nymphs suffered significantly higher percentage mortalities 17.8, 59.2 and 66.6% respectively, during the peak period of defoliation which occurred during the eighth week of sampling (DMRT, df=32,$P < 0.05$). Thereafter, the mortalities of all the stages decreased to 2.0, 10.1, 13.2 and 5.2% of eggs, larvae, nymphs and eggs respectively during the ninth week when sampling was terminated. The stages of M. tanajoa were significantly correlated with corresponding population densities of eggs ($r = 0.89$), larvae ($r = 0.67$ NS). nymphs ($r = 0.98^{*}$) and adults ($r = 0.98$, df=6, $P < 0.01$).

Sex ratio of M. tanajoa (males:females) during the period of sampling is presented in figure 12.3. This figure shows that there was initially significantly higher proportion of females (> 60%) than males (> 40%) (X^2-test, $X^2=16.75$, df=8, $P < 0.05$). However, the proportion of males increased during the period of peak population density. This increase of males occurred during the sixth and seventh weeks when the proportion of males increased to maximum

38.0% and 40.2% respectively while those of female increased from 62.0% and 59.8% respectively., After the occurrence of adult peak density, the proportion of female to males increased again to 67 and 77% during the eighth and ninth weeks respectively.

Level of oviposition preference of female M. tanajoa on young and mature leaves during the sampling period is presented in figure 12.4. This figure indicated that the highest number of eggs were laid on young leaves than on the old leave. Besides more females were also found on the young leaves than on the old ones. However, there was no significant difference between the eggs laid on the old (25.0 eggs) and the young leaves (48.3 eggs) (t_{28}=2.67 ,P < 0.05) during the first week of sampling (i.e. two weeks after introducing the females). Thereafter, the eggs laid on the young leaves were significantly higher than those laid on the old leaves (DMRT, df=28, P < 0.05) throughout the sampling period. Besides, there were also significantly higher number of females on the young leaves than there were on the old leaves starting from the fourth to the eighth weeks (DMRT, df=28, P < 0.05). The number of eggs laid on the young leaves were positively and significatnly correlated with the females on the same leaves (r= 0.953, P<0.01, df=6) and eggs on old leaves and females on the same leaves were also positively and significantly correlated (r = 0.971) (P < 0.05, df=6).

Further, percentage leaf chlorosis due to the feeding of M. tanajoa is presented in figure 12.5. This figure indicated that mean leaf chlorosis increased progressively from 0.0% during the first week to 80% during the seventh and eighth weeks of sampling. The mean percentage chlorosis which occurred during the first and second weeks (10.0 and 15.0%) were significantly lower than those occurring during the 3^{rd}, 4^{th} and 5^{th} weeks (19.2, 30.0 and 41.9% respectively, $F=5.11$, $df=8, 32$, $P<0.05$). Yet another significant rise in leaf chlorosis occurred from 60.3 to 80.2% during the 6^{th} to the 8^{th} weeks respectively (DMRT, $df=32$, $P < 0.05$). But, leaf chlorosis which occurred during the 7th and 8th weeks (80.0 and 82.0%) were not significantly different at the same level of probability. Besides, it was observed that when most leaves' score 5, which was equivalent to 80% loss of chlorophyll, they began to senesce and drop-off the plant starting from the tip of the shoot. Mean leaf chlorosis (percent) was significantly correlated with the mean population densities of nymphs ($r = 0.878$, $P<0.01$, $df=6$) and adults ($r = 0.918$) while it was not significantly correlated with eggs ($r= 0.69$ NS) and larvae ($r =0.53$ NS) ($P < 0.05$, $df=6$).

Percentage leaf defoliation of the plants infested with M. tanajoa is presented in figure 12.6. This figure indicated that leaf defoliation began on the fifth week of sampling (i.e. nine weeks after artificially infesting the plants). Initial mean leaf defoliation which occurred during the 5^{th} weeks (5.0%) was significantly lower than those of the subsequent weeks except that of the 6^{th} week (15.4%) ($F=3.23$, $df=7,28$, $P < 0.05$). Thereafter, mean leaf defoliation increased steadily with the maximum leaf defoliation occurring during the eighth week (76.3%) and it was significantly higher than that which occurred during the seventh week (40.2%) (DMRT, $df=28$, $P < 0.05$). Leaf defoliation often stated with the second and third leaves from the tip of the shoot and progressed downwards. The leaf defoliation was slow. Severe leaf defoliation left the tip of the shoot resembling a 'candle stick' appearance.

Reduction (percent) in cassava leaf biochemical components due to the feeding of M. tanajoa is given in table 12.1. This table showed that chlorophylls a and b were reduced by 32.59 and 49.55% respectively while the dry matter was reduced by 15.83% in the mite damaged leaves. Moreover, the calcium, potasium, sodium, nitrogen, zinic Manganese and maguesium were reduced by varied percentages of 47.30, 16.3, 38,82, 48.73, 68.42, 46.55 and 33.33 respectively in the mite damaged leaves. The crude protein

was reduced by 53.17% in the leaves damaged by M. tanajoa. Apart from chlorophyll b, large amounts of calcium, sodium, nitrogen, zinc and manganese were reduced by the mites feeding compared with those in the undamaged leaves.

12.4 DISCUSSIONS

Results indicated that maximum population density of M. tanajoa reached a economic damage level when their feeding process caused the maximum leaf damage. The symptoms of mite damage appeared on the cassava leaves on the fifth week after artificial infestation of the plants with the mites. Similar results have been reported by Ezulike and Eguatu (1990) but their symptoms appeared earlier at two weeks after infestation. Although, this study has shown that damage threshold of M. tanajoa adults was 76.4 adults/leaf, they found that their damage threshold was only 20 active stages but this figure was low because,probably, they counted all the leaves; consequently, they obtained that average of that per leaf. Therefore, if the sampling was limited to the area of the plant where the mites were distributed, then the damage threshold was 76.4 adult (males and females) per leaf. This constituted an estimate of economic damage level with respect to mite populations and/or foliar damage.

Therefore, it would be advisable to apply some control measures once the mite population exceeded this level. Byrne et al (1983) suggested that when the damage threshold was exceeded, then selective acaricide should be applied or mass release the appropriate predators. They also,

suggested that beyond the damage threshold the mite populations would cause economic yield loss on the crop. In areas where the cassava leaves are eaten as vegetable, the quality of the leaves would be reduced thereby making it inedible because consumers tend to look for healthy leaves.

Further, William and Ghazali (1969) found that maximum leaf expansion of cassava leaves occurred during the fourth and fifth months, while Beck (1960) observed that tuber formation of cassava took place during the sixth month after planting (of course, this depended on the variety). In this study mites approached their maximum densities during the 12^{th} week or three months after planting. Since this was the period of maximum photosynthesis and dry matter accumulation, it is postulated that since there was abundance of suitable food source, the reproductive rates and total survival of the mite were enhanced to their maximum. These high reproductive rates and total survival culminated into very high population density and the feeding such that leaf damage became extensive. When the feeding became correspondingly extensive food nutrients of the leaves were depleted. Then a self-limiting process was introduced because reproduction, development and survival were adversely affected as the leaves become bronzed.

Further feeding was hindered by the accumulation of waste products and cast skins on the leaf surface. Nyiira

(1975) had similar observations on this pest while McMurtry (1970) also observed the same process in the populations of Oligonychus punicae (Hirst) on avocado leaves.

Therefore, this phenomenon of intraspecific competition was responsible for the massively high mortalities of stages of the mite. In this case, populations of various stages of the mite increased rapidly as long as the host plants' leaves were healthy and provided all their nutritional requirements. But the high population densities depleted the food source and often the active stages particularly females dispersed to other plants while the juveniles died of starvation. A large number of females were suspended on webs and silken threads and this indicated their readiness to disperse to found new colonies as has been the case in spider mites. Suskin and Naegele (1966) reported that under conditions of high mite density and host plant damage, T. urticae underwent a change in behaviour pattern which culminated in dispersal from the host plant. Hussey and Parr (1963) noticed that T. urticae in glasshouses moved up the plant and began to abandon or emmigrate from the host plant when all the apical foliage was damaged.

Besides, the proportion of males increased markedly from the previous proportion during this period of high density. And as the deterioration of the leaves progressed these males became more active than the famles. This

observation was supported by the fact that the dispersing stage tended to be mated females. Mitchell (1973) and McEnroe (1969) noted similar observations.

Different mite stages showed varying degrees of mortality during defoliation. The egg stage suffered the highest mortality during this period presumably as the leaves dried, moisture on the leaf surface was reduced and as a result of low atmospheric relative humidity, the egg collapsed or became dehydrated. Secondly, the larvae starved to death because it could not find sufficient nutrients to feed on as a consequence of nutrient depletion due to the intraspecific competition as explained above.

Thirdly, the larval stages's inability to disperse (as this study has shown that the stage found on the penels were predominantly females and some males, 10.3). Since the total nymphal development period was long, presumably, many of this stage died on the drying leaves before development was completed. And the lowest mortality was obtained in females which was so, evidently, because at high density the females dispersed as soon as they emerged.

Moreover, the foregoing results have shown that M. tanaja had preference for the young leaves, and that chlorosis increased with the period of infestation. Consequently, young leaves suffered the highest chlorosis

and subsequent defoliation because this mite fed by piercing individual cells with their stylet - like mouth parts and extracted the cell contents (Tomczk and Kropczynka (1985). Subseqent defoliation or leaf drop was presumably, due to excessive extraction of cellular contents of the leaves to the extent where the leaves senesced. Wayman (1981) reported significant reduction in photosynthesis and transpiration caused by high densities of T. urticae, which resulted in stress of other physiological activities of its strawberry host plant. Moreover, Tomczk and Kropczynka (1985) reported that T. urticae depleted the cell content with subsequent poor or total collapse of transpiration process and a decrease in water content of the leaf. Tanigoshi and Davis (1978) noticed that tissues damaged by T. mcdanieli had lower number of cells than undamaged tissues. They approximated that damaged apple cells were reduced by 35 - 55%. They also observed that the injured cells were deformed, their chloroplasts were lacking and the cells were sunken.

Results of this study revealed marked reduction of chlorophylls a and b which were reduced by 32.59 and 49.55% respectively. In the mite-damaged leaves, it was assumed that M. tanajoa sucked up the chloroplasts of the cells as it fed on the leaf cells. The suggestion that it sucked the chloroplasts was further confirmed by its dark waste matter which it deposited on such leaves. Ayanru and Sharma (1983)

had similar results from mite-damaged leaves. Other cellular components such as calcium, sodium, potassium nitrogen and crude protein were also reduced in varied amounts. Zukova (1963) studied the biochemical activities associated with the feeding of T. urticae on cotton. She found reduction of total protein, non-proteinic nitrogen and crude protein in mite damaged leaves. Ezulike and Eguatu (1990) had similar observations on mite damaged leaves compared with undamaged ones. Besides, they found reductions in cyanide content, moisture, amino acids and fat in the mite - damaged leaves.

Therefore, it can be concluded that M. tanajoa had detrimental effects on its host plant. Its damage threshold was reached gradually but steadily such that the host plant became over-exploited at high population densities. The high population density resulted in intraspecific competition whereby subsequent high mortalities of juveniles and dispersal of the females occurred. The host plant leaves became extensively damaged by the mite and became chlorotic and eventually senesced and defoliation occurred. Later, the host plant regenerated new leaves but the small residual population of eggs which survived in the crevisces hatched and continued the mite infestation. Damage of the leaves' by the mites were evidenced by the marked reduction in the leaves' biochemical components. When cell components

were severely reduced, the cells collapsed and the leaves dried thereby killing some of the stages of the mite.

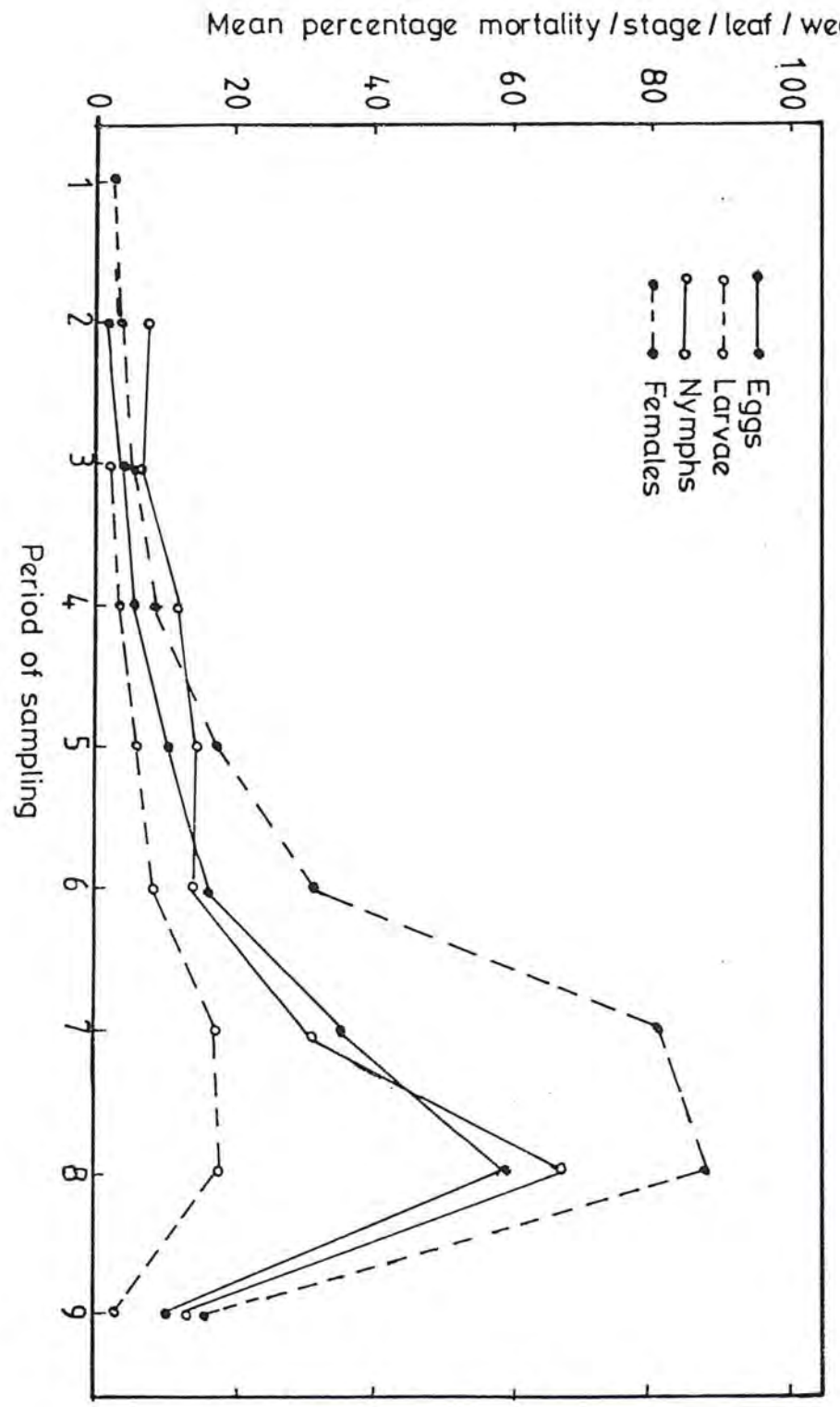

Mean percentage mortality / stage / leaf / week
0
20
40
60
80
100
Eggs
Larvae
Nymphs
Females
1
2
3
4
5
6
7
8
9
Period of sampling

Fig. 12.1

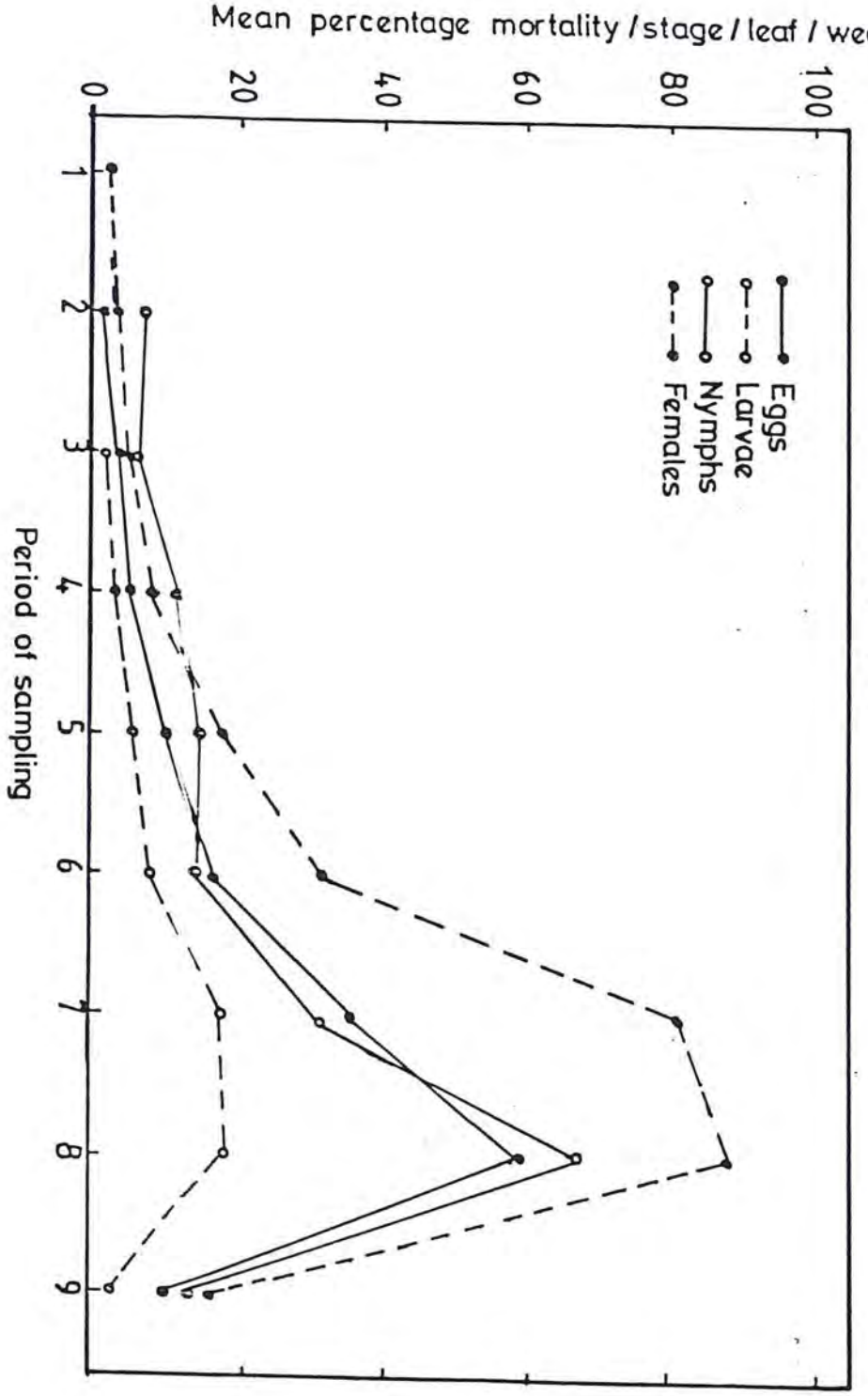
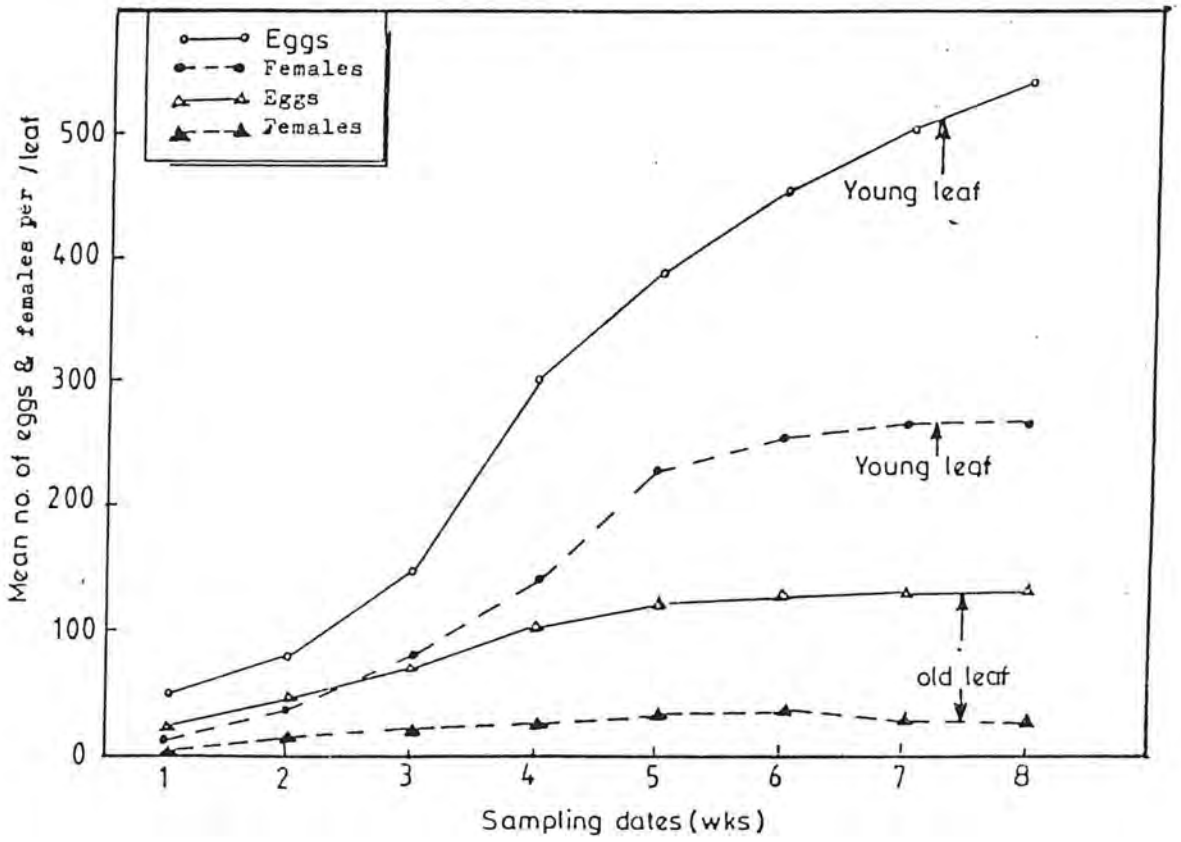

Mean percentage mortality / stage / leaf / week
0
20
40
60
80
100
Eggs
Larvae
Nymphs
Females
Period of sampling
1
2
3
4
5
6
7
8
9

Fig. 12. 2

Fig. 12.3


Eggs
Females
Eggs
Females
Mean no. of eggs & females per /leaf
500
400
300
200
100
0
Young leaf
Young leaf
old leaf
1
2
3
4
5
6
7
8
Sampling dates (wks)

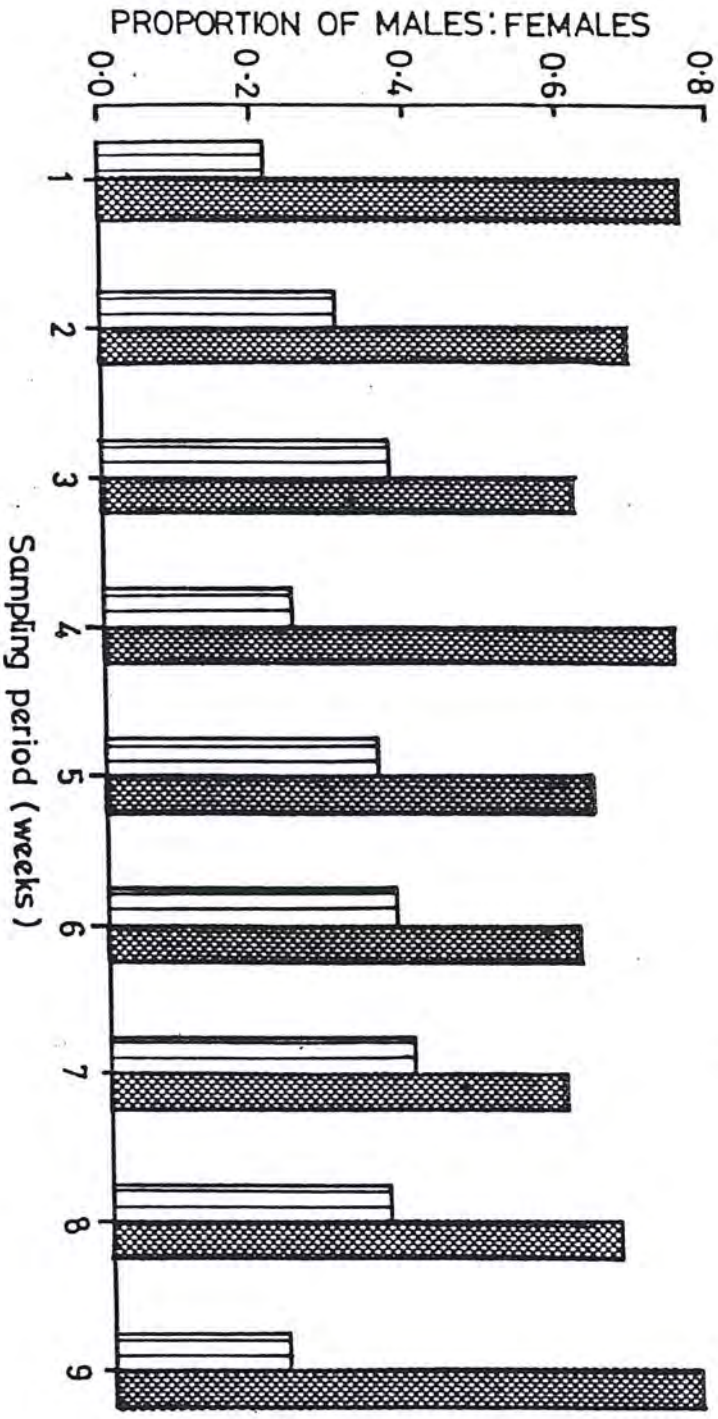

PROPORTION OF MALES: FEMALES
0·0
0·2
0·4
0·6
0·8
Females
Males
Sampling period (weeks)
1
2
3
4
5
6
7
8
9

Fig. 12.4

Fig. 12.5

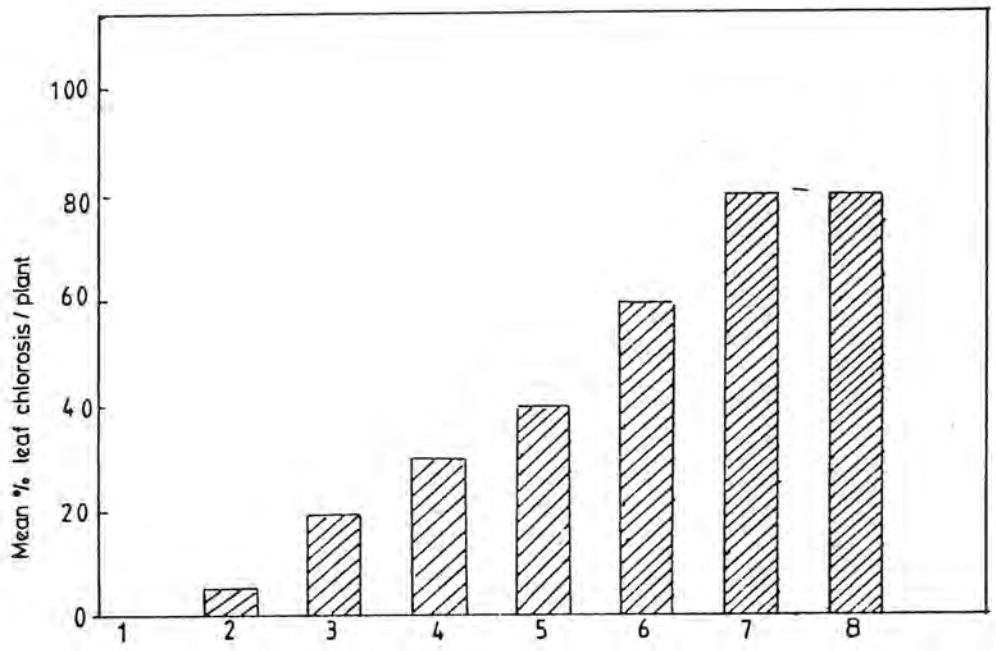


Fig. 12.6

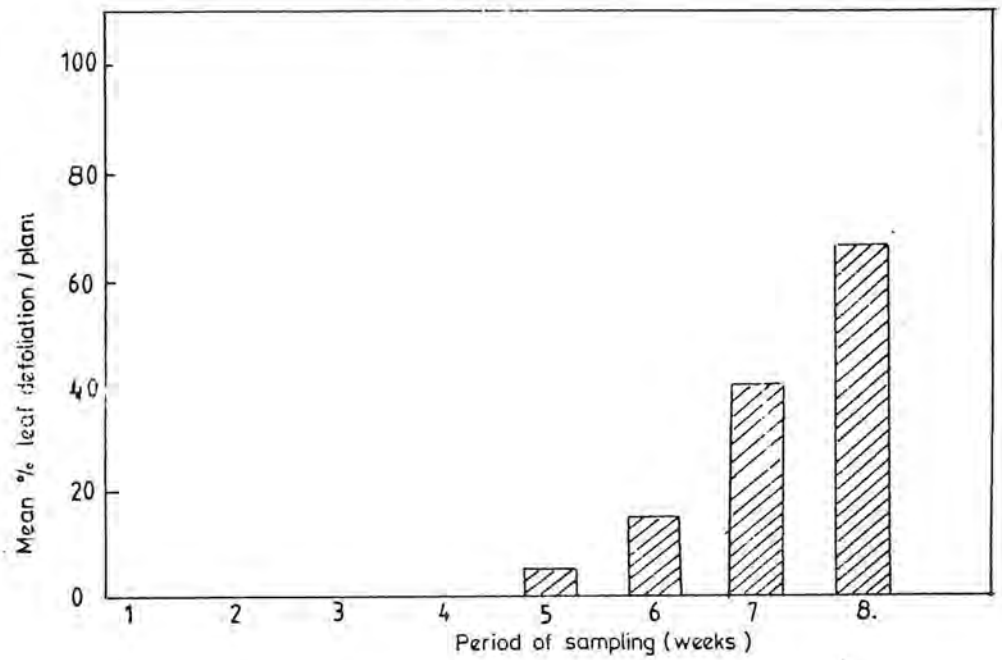


Table 12.1 Reduction (percent in cassava leaf biochemical components due to infestation by *M. tanajoa*.

Analysed leaf biochemicals		Undamaged leaves	Damaged leaves	Reduction (%)
Chlorophyll a(g/g)		0.135	0.091	32.59
Chlorophyll b.(g/g)		0.111	0.056	49.55
Dry matter	%	31.28	26.33	15.83
Calcium	"	1.48	0.78	47.30
Potassium	"	0.49	0.41	16.33
Sodium	"	0.85	0.52	38.82
Nitrogen	"	4.33	2.22	48.73
Zinc	"	0.38	0.12	68.42
Manganese	"	0.58	0.31	46.55
Crude protein	"	32.52	15.23	53.17
Magnesium	"	0.72	0.48	33.33

GENERAL CONCLUSIONS

Monitoring of field population of M. tanajoa and its locally occurring predators revealed that field populations of this mite had very violent oscillations of temporal fluctuations which were influenced by the relative abundance of the indigenous predators and weather factors. The pest population declined when the populations of the predators were increased. Persistently, high ambient temperatures occurring during the hot dry weather (i.e. above 24°C) enhanced the pest population's capacity for increase. On the contrary, the high rainfall with its varied intensities caused significant percentage mortalities among the various developmental stages of this pest with subsequent decline in the pest population.

Among the naturally occurring predators, the following predator species were found to be closely associated with M. tanajoa both at ICIPE - Mbita Point Field Station and Rusinga Island in western Kenya, namely, I. degenerans and N. teke (Acarina : Phytoseiidae), H. fageli (Coleoptera :Staphylinidae) and S. morelletti (Coleoptera : Coccinelidae).

Study of the biology and population growth rates of both M. tanajoa and its phytoseiid predators under laboratory conditions at 25 ± 1°C in growth chambers revealed that both the mite and the phytoseiid predators had four developmental stages, namely, egg, six legged larva, protonymph and deutonymph before moulting into adult . However, between the developmental stages of M. tanajoa starting from the larva, there were quiescent periods which occurred prior to each moult corresponding to protochrytsalis, deutochrysalis and teliochrysalis stages. Besides M. tanajoa males had shorter developmental periods than their female counterparts. Subsequently, males emerged earlier than the females and this phenomenon of early maturing of males ensured that females of the same generation were mated before emigrating to found new colonies. Therefore, this species though arrhenotokous, it has maintained both males and females in its populations.

Moreover, this study revealed that female M. tanajoa had longer developmental, preoviposition, oviposition, post-oviposition periods and longevity than its phytoseiid predators. Besides, this pest had longer generation time (T_g = 14 - 16 days), higher net reproductive rate (R_0 = 290.03), higher intrinsic rate of natural increase (r_m = 0.41) and higher finite rate of increase (λ = 1.507) compared to those of its phytoseiid predators. Therefore, it can be concluded that the high values of the foregoing

parameters of population growth rates for M. tanajoa serve as evidence that the population of this pest was usually much larger than those of its predators combined. Subsequently, the impact of predation on the field population was negligeable compared with the superior reproductive capacity of this pest.

As the temperature increased from 20 to 27 ± 1°C both embryonic and post embryonic developments were eccelarated; pre-oviposition and oviposition periods were reduced; fecundity, eclosion and survival rates were increased. The parameters for population growth rates also increased with temperature for both M. tanajoa and its phytoseiid predators. Therefore, it can be concluded that the increase in temperature from 20 to 27 ± 1°C, which is a common occurrnce within the tropics, favoured the population build-up of this pest. Since this pest's rate of population increase was higher than those of its predators, outbreaks of this pest became frequent during periods of high temperatures whenever it was hot and dry.

Determination of functional and numerical responses of the indigenous predators at 25 ± 1°C indicated that the phytoseiid predators' functional responses to the various densities of stages of M. tanajoa were predominatly type II while those of H. fageli fourth instar larva and adult were type III and V respectively. Thus, the phytoseiids were

more effective at low prey densities while the staphylinid, H. fageli was more effective at high prey densities. Therefore, it was concluded that the two groups of predators i.e. the phytoseiids and the staphylinid, could be used to argument each other during low and high prey densities respectively. In order, to achieve control of this pest in field situation, mass rearing and artificial field releases are recommended.

M. tanajoa was strongly preferred to T. cinnabarinus at low and high densities of single or mixed species. Although, T. cinnabarinus population was usually low in the field situation, it provided a suitable alternative food source during the periods when the population density of M. tanajoa was low. Therefore, it was not a competitor of the cassava green spider mite but rather a supplement on which the predators would survive during the absence or low density of M. tanajoa

Control of the cassava green spider mite in caged experiments using its indigenous predators revealed that the predators were capable of reducing the population density of this pest by about 33% when they had been released in cages. However, due to the predators low numerical responses and/or low intrinsic rate of population increase, this pest recovered and exceeded its former population density. In spite of the apparent successful initial control impact on

the pest, a field trial would be recommended so that information would be obtained on precisely what happened in the field situation with mass releases of these predators.

Further, the assessment of the dispersal capacities of the two phytoseiid predators in the screenhouses revealed that although both I. degenerans and N. teke dispersed within and between the host plants, N. teke dispersed faster than I. degenerans. Whereas, I degenerans tended to aggregate on the lower surfaces of the leaves on the lower stratum of the plant N. teke moved faster and dispersed spersely among the shoots. Subsequently, these differences in predators' distribution resulted in/to delayed impact on the prey populations. Both M. tanajoa and its two predators emmigrated from the plots in the direction of the prevailing winds as their respective densities increased.

Assessment and determination of the effect and mechanism(s) of rainfall intensities on population of M. tanajoa and its phytoseiid predators showed that 'light' rainfall caused highest mortality on eggs and larvae. But, 'heavy' rainfall intensity caused high mortalities among all stages of M. tanajoa. However, the three rainfall intensities tested caused heavy mortalities among the various stages of the phytoseiid predators particularly I. degenerans' eggs. The stages of both the prey and predators were killed by being mechanically hit and dislodged from the

host plant leaf onto other unfavourable sites where they were drowned by the 'run-off' from the 'rain'. The eggs embibed water and burst especially the newly laid ones. Therefore, percentage mortality caused by 'light' "moderate" and 'heavy' rainfall intensities on M. tanajoa and its predators showed that this environmental factor was an important source of mortality for this pest and its indigenous predators. However, both the pest and its phytoseiid predators were not erradicated because a residual population always remained to perpetuate their species even after the wet season.

Determination of the effect of population density of this mite on its host plant cassava revealed that as the population density of this mite increased on the host plant, it increasingly caused chlorisis of the preferred young leaves. The high population density of mite resulted in over- exploitation of the food source by excessive feeding which resulted in depletion of chlorophyll component of the cell with subsequent defoliation of the leaves of the host plant and heavy (88.3%) mortality of the adult mite. This phenomenon was a common occurrance during the hot dry weather and although it was often thought to be due to the prevailing dry spells, it has been hereby proved that heavy population density of this pest caused defoliation of the host plant through its excessive feeding and subsequent reduction of biochemical component of leaves.

In summary this study has revealed that although there are indigenous predators of M. tanajoa, they have failed to suppress the population of this pest because it has much higher population growth rate and reproductive potential than those of its indigenous predators. Other mortality factors such as rainfall reduce the population of this pest but a residual population always remained on the crevisces and folds of the terminal and lateral buds. This residual population increased very quickly to high population density because this pest had high reproductive potential. This pest reduced the biochemical components of the cassava leaves and thereby probably, reduced the crop yields. Therefore, the population fluctuations of this mite in the field have been proved to be due to environmental factors such as rainfall and temperature, and suitability of the host plant coupled with the self-limiting process which is a characteristic of the tetranychids.

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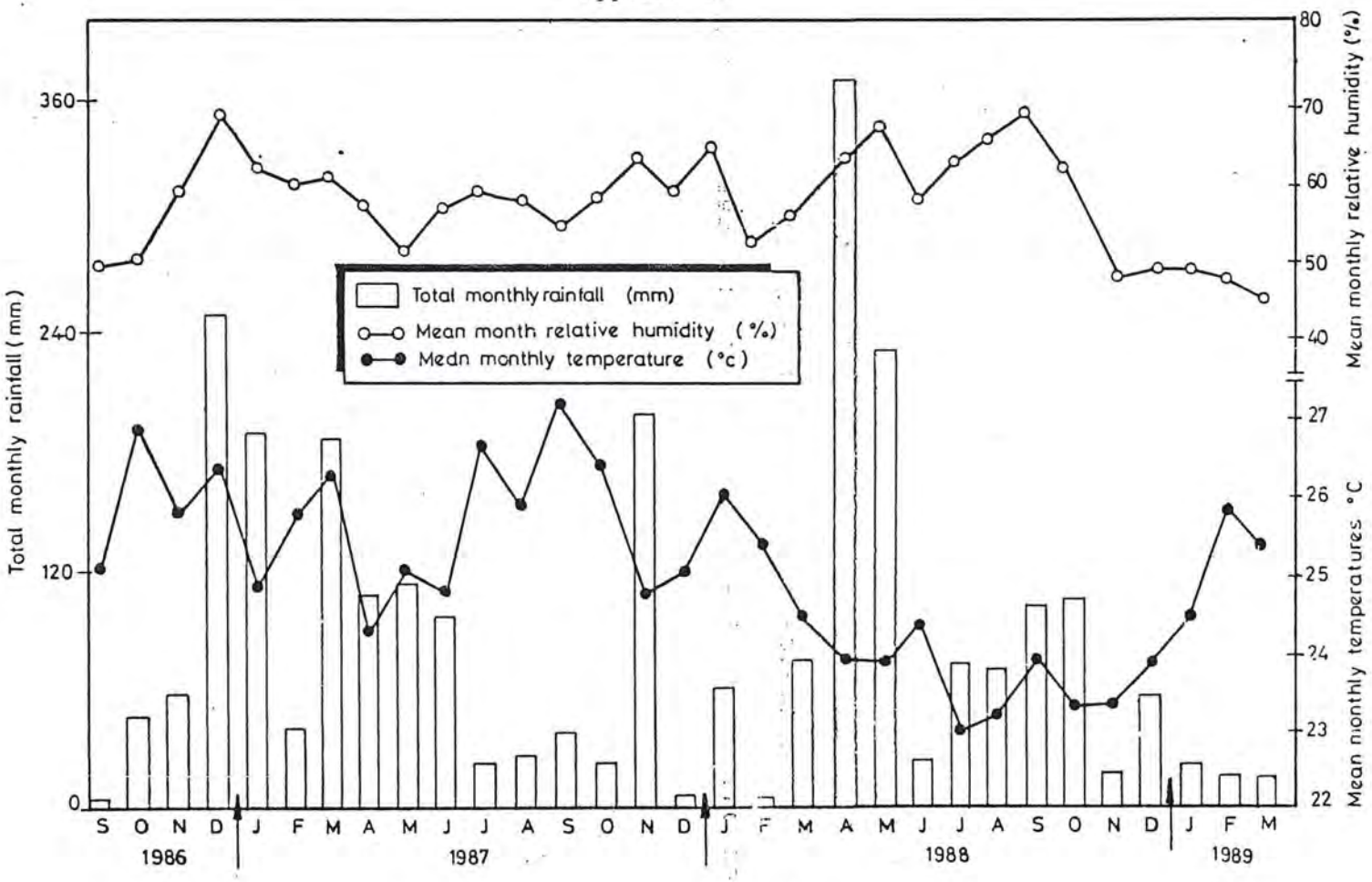
A P P E N D I C E S.

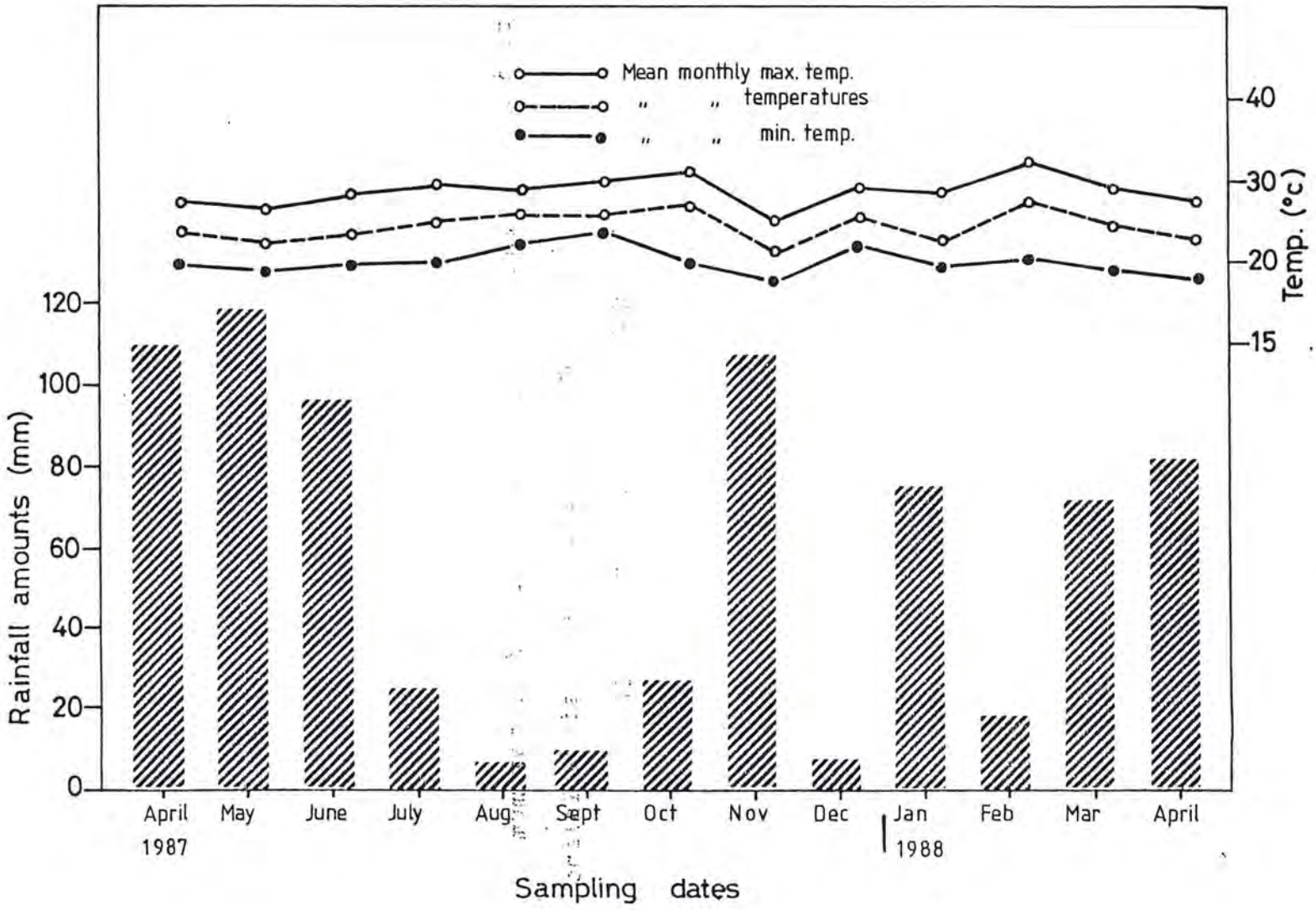
Appendix 1. Mean monthly rainfall, temperature and relative humidity at M.P.F.S from September, 1986 to March, 1989.

Append. 1


Total monthly rainfall (mm)
Mean month relative humidity (%)
Medn monthly temperature (°c)
Total monthly rainfall (mm)
Mean monthly relative humidity (%)
Mean monthly temperatures °C
360
240
120
0
80
70
60
50
40
27
26
25
24
23
22
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M
1986
1987
1988
1989

Appendix 2. Mean monthly record of rainfall maximum and minimum temperatures at Rusinga Island from April, 1987 to April, 1988.

Append. 2


Mean monthly max. temp.
" " temperatures
" " min. temp.
Rainfall amounts (mm)
0
20
40
60
80
100
120
Temp. (°c)
15
20
30
40
April 1987
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan 1988
Feb
Mar
April
Sampling dates