MANAGEMENT OF *Tetranychus urticae* Koch (ACARI : TETRANYCHIDAE) ON ROSE IN POLYHOUSE CONDITIONS USING *Amblyseius longispinosus* (Evans) (ACARI : PHYTOSEIIDAE)

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
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CERTIFICATE

This is to certify that the thesis entitled "**MANAGEMENT OF *Tetranychus urticae* Koch (ACARI : TETRANYCHIDAE) ON ROSE IN POLYHOUSE CONDITIONS USING *Amblyseius longispinosus* (Evans) (ACARI : PHYTOSEIIDAE)**" submitted by **Mr. Ramesh Vaidya** for the degree of **MASTER OF SCIENCE in AGRICULTURAL ENTOMOLOGY** to the **University of Agricultural Sciences, Bangalore**, is a bona-fide record of research work done by him during the period of his study in the University under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I INTRODUCTION

Rose belongs to the family Rosaceae, which comprises of 120 species and about 20,000 cultivars. It is generally regarded as the Queen of flowers because of the varied colours, architecture and fragrance. In India it is grown on 5,498 hectares. In Karnataka rose covers an area of 1,465 hectares, the annual production being 3,817 tonnes.

India has 35,000 hectares of land under floriculture, mostly for production of flowers for domestic market estimated at Rs.205 crores. This compares very poorly with The Netherlands which despite having only 3,600 hectares of land under floriculture controls 65 per cent of the global market.

Roses are used for making garlands, bouquets and in adornments. It is processed to obtain ghulkand, rose oil, attar and rose water. Rose stands first in the world, cut-flowers Gowda *et al.* (1990).

The cultivation of cutflowers in India under greenhouses has increased from few hectares during 1979-80 to nearly 300 hectare during 1994-95. Floriculture industry is concentrated around Bangalore, Pune, Delhi, Hyderabad, Nasik and Trivandrum (Gowda and Jayaprasad, 1997). In India floriculture export has gone up from Rs.65 million to about Rs.179 million in the 1993-94. India's share in world flower trade is just 0.70 per cent which is negligible.

Modern breeding techniques have helped obtaining attractive colourful flowers having greater export value. However, these plants are more susceptible to pests and diseases. Among the pests mites are the major, under polyhouse and in open field conditions. Increase in pest problems has lead to indiscriminate use of pesticides resulting in the resurgence of mites. Recently in most of the polyhouses the level of resistance to dicofol and other acaricides has been observed to be very high. Hence even with very frequent spraying of pesticides, it has not been possible to bring down the population of mites to manageable level in most of the polyhouses.

To over come these limitations, it is essential that eco-friendly approaches are explored which would be safer to the environment in the Indian context. The utilization of natural enemies including mite, predator, fungal, bacterial, viral pathogen etc., has remained an unexplored area in this country. Among mite predators, phytoseiids are most promising. More than 1,200 species are known from the world, and 139 species have been reported from India (Gupta, 1986). Many have been collected in association with tetranychids and other mites.

Laboratory studies have shown that some of these phytoseiids are capable of eliminating the prey within a short period when released in appropriate ratios (Mallik, 1974). Mass multiplication is possible though not very easy, especially if they are obligatory predators (Anil, 1990). Few Phytoseiids like, *Phytoseiulus persimilis* (Athias-Henriot), *Amblyseius fallacis* (Garman) and *Typhlodromus limonicus* Garman have been widely studied and used in biocontrol of plant feeding mites in other countries.

The phytoseiid predator *Amblyseius longispinosus* (Evans) has a wide distribution, and ability to adopt to warm temperature inside polyhouses under South Indian conditions (Mallik *et al.*, 1998). It is a promising predator which can suppress the spider mite population. There are virtually no reports on management of spider mites using phytoseiids under polyhouse conditions from India. The present study was undertaken to fill the lacuna with the following objectives :

1) Developing a sampling method for *Tetranychus urticae* Koch infesting rose plants in polyhouses.

2) Assessing the feeding capacity of *Amblyseius longispinosus*.

3) Studying the dispersal capacity of *Amblyseius longispinosus*.

4) Assessing the number of *Amblyseius longispinosus* required for suppressing the prey *Tetranychus urticae* infesting rose plants in polyhouses.

5) Developing a model for mass production of *Amblyseius longispinosus*.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Literature on biological control of red spider mite *Tetranychus urticae* Koch, is scarce, wherever adequate information was not available literature on aspects related to this investigation is presented.

2.1 Sampling Programmes :

A sequential decision plan was developed in field studies in Idaho in 1982 for assessing the economic status of a *Tetranychus urticae* on beans *(Phaseolus vulgaris).* Precision and cost analysis showed that sample units should consist of single trifoliate leaf, picked from the bottom one third of the plant canopy. Provisional economic thresholds were established for 2 pre-harvest intervals in terms of proportion of leaves infested with ≥ 5 and ≥ 10 mites/leaf. Upper and lower critical limits of the sequential decision plan were defined by the confident interval, $i = (Pi)\ (n) \pm (t)\ (n)\ [Pi\ (1\text{-}Pi)]\ n$. Where 'Pi' = is the economic threshold, 'n' is the number of leaves examined and 't' is the students 't' statistic for the acceptable error level (Bechinski and Stoltz, 1985)

Perring *et al.* (1987) determined intraplant distribution of all life stages of *T. urticae* on Cantaloupe in California. Counts of adult females were used to estimate total population size. Significantly more adult females were present on the primary branch indicating that this branch was optimal for use in the sampling scheme. Temporal changes in mite distribution on the primary branch indicated that plant phenology was an important factor to be considered in developing a sampling strategy. Optimum number of adult females of *T. urticae* were counted on three consecutive leaves of the primary branch, location of these leaves on the branch varied with plant growth stage.

Nyrop *et al*. (1989) developed, sequential sampling procedure for classifying the density of European red mite, *Panonychus ulmi* (Koch), with respect to four critical densities (2.5, 5.0, 7.5 and 10.0 mites per leaf). Frequencies of erroneous classifications made using these sampling procedures and average sample sizes required to make classifications were compared with sequential sampling procedures that used complete counts of mites on leaves. The binomial procedures required approximately the same

average sample size and had approximately the same frequency of erroneous classifications. The sample size efficiency of the binomial sequential classification sampling plan was compared and found superior to the sample size efficiency of an estimation procedure based on binomial sampling. Field testing of one of the binomial sequential classification sampling plan showed that it rapidly and correctly classified mite densities.

Krainacker and Carey (1990) studied, within plant distribution and population patterns of *T. urticae* on field corn in Sacramento River delta. Eggs, immatures, quiescent females, deutonymphs and adults of both sexes were counted on each leaf of all plants sampled. Population of each stage increased gradually the first month of the season, then rapidly rose to peak levels. Population peaked between sixth and eighth week of the study, then rapidly crashed. Mites aggregated on the lower leaves early in the season and on the mid-plant leaves towards the end of the season. Most mites did not reach the upper leaves. The results suggested that mite sampling could focus on the number of females on lower leaves, early in the season.

Hepworth and MacFarland (1992a) established an empirical relationship between the mean density of *T. urticae* on strawberries and the proportion of mite-free leaflets from the results of 170 samples taken during the two growing seasons (1988-1990) in Victoria, Australia. Confidence intervals for the mean density predicted from a presence-absence, samples were derived and an adjustment was made to account for sample not being truly random. A sampling plan was proposed that can be adopted readily by growers wishing to implement integrated control of *T. urticae* on strawberries. Following a systematic sample of 100 leaf lots, it is recommended that the predator *Phytoseiulus persimilis* be released if the proportion of mite-free leaflets falls to 75 per cent and that spraying with an acaricide is undertaken when it rises to 5 per cent.

Hepworth and MacFarland (1992b) proposed a range of expressions for the variance of estimates of pest population densities based on presence-absence samples. An equation of the form $\ln(m) = a + b \ln(-\ln p)$ was used to relate m, the mean density of mites in a sample, to p, the proportion of uninfested sampling units, the derivation of the variance and accompanying assumptions were examined. Because many presence-absence

samples are not truly random, they proposed that an adjustment be made to the term in the variance that results from sampling. This adjustment called the design effect was illustrated using results of two spotted spider mite, *T. utricae* Koch population on strawberries and was shown to be greatest for large values of p.

Mari and Comelles (1992) analysed data on active stages of *Panonychus ulmi* from 709 samples taken in apple orchards in Lleida and Valencia, Spain during 1987-89, to determine the distribution parameters and to find a simplified sampling procedures. There were no differences in clumping patterns between orchards and years, so overall indices of Taylor and Iwao were calculated. The values for Taylor's (b = 1.39, r = 0.93) and Iwao's (alpha = 1.17 ; r = 0.960 beta = 1.17) parameters suggested that the active stages of *P. ulmi* were fairly clumped on the leaves, and the aggregation was higher between individuals than between colonies. The proportion of leaves infested with active stages or females showed a good correlation with the number of active stages per leaf, making binomial sampling a practical method.

Nyrop and Binns (1992) developed sequential sampling plans based on presence absence counts. Two models that relate the proportion of sample units more than 'T' (tally threshold) organisms [PCT] to mean density (m) were considered. An empirical model of the form ln [-1n (1-P(t))] = rΔ ln (m) where m is mean density, and the negative binomi al distribution (NBD). The robustness of the sampling plans that used T = 0 poor. Expected Operating characterstic and average sample number functions for sampling for sampling plans based on the two P(T) –m models were similar. Robustness of sampling plans based on NBD imporved significantly with larger values of T. When sampling using thresholds of 2.5, 5.0 and 7.5 mites per leaf, recommended values of T are 4, 6 and 7 respectively.

Gonzalez-Zamora *et al.*, (1993) sampled *T. urticae* and *Amblyseius californicus* (McGregor) from strawberries in Spain between August 1988 and July 1991, and developed the sequential and binomial estimation sampling programmes. The distribution of the mite population agreed with Taylor's Power Law. It was suggested that sampling only females of *T. urticae* gave a good approximation than sampling of all motile stages. Using sequential estimation, 25 and 35 leaflets were required to estimate the population den ty of females and motile stages respectively at threshold density of 7 females and

20 motile stages/leaflet. In case of motile stages of *A. californicus,* 75 leaflets were required to estimate low density populations (0.5/leaflet). The binomial estimation sampling programme was developed by estimating the relationship between population density and the proportion of leaflets with 'T' or less individuals. For *T. urticae* the cut-off number 'T' was 4 and 9 for females requiring 65 and 93 leaflets to estimate the population near the threshold density. To sample *A. californicus* based on the negative binomial distribution, 125 leaflets were necessary at low densities.

Castagnoli *et al.* (1993) reported the spatial distribution of *T. urticae* on soybeans in Italy. Calculated coefficients were used to determine the size of samples required for estimating population means with fixed levels of precision and the relationship between the proportion of infested leaflets and the mean number of mites. Samples of about 100 leaflets provided a good estimate with mite densities higher than 5/leaflet. Binomial sampling was suitable when the densities of *T. urticae* were < 40 mites /leaflet ; at higher densities, all the leaflets were occupied. The association between *T. urticae* and its predators *A. californicus* and *A. rademacheri* was tested and found to be positive only for *A. californicus.*

Zhang and Sanderson (1995) reported that most spider mites were found on the lower canopy when their overall density was low. More mites were found on the upper canopy when their density increased especially in the absence of predators. Both, spider mites and predators, were strongly aggregated. The dispersion of spider mites was similar in the upper and lower canopy and was not affected by the presence of the predator. Regressions of predator density on prey density revealed 44 per cent positive density dependent aggregation. The strength of the aggregation increased with the predator density and was positively associated with the suppression of prey population. The spider mite population growth was negatively related to both predator and spider mite density. The effect of predator density on growth rate was 35 times greater than that of spider mite density.

Devi and Rai (1996) analysed the spatial distribution of *T. cinnabarinus* Boisduval and *Amrasca biguttula biguttula* on okra *(Abelmoschus esculentus* (Linn.)) using the negative binomial common 'K' Taylor's power law and Iwao's regression. A common

'K' could be fitted to all the data. Taylor's power law gave a good fit than Iwao's regression method. Using Taylor's regression co-efficient, optimum sample size and sequential count plans were developed.

2.2 Functional and Numerical responses of *Amblyseius* sp. :

Chant (1961) reported type-I response curve for the phytoseiid *Typhlodromus occidentalis* (Nesbitt) feeding on *T. urticae* Koch. Sandness and McMurtry (1970) studied the functional responses of *Amblyseius largoensis* Muma, *Amblyseius concordis* Chant and *Typhlodromus floridanus* Muma to different densities of *Oligonychus punicae* Hirst, and the response for each of the species was found to be type-II.

Mori (1969) reported the functional response of *A. longispinosus* to *T. urticae.* Starting with different numbers of nymphs and females and a gravid female of the predator on two different substrates, namely paper and leaf of beans, he noted that the number of prey consumed decreased significantly at higher prey densities and thus got a dome shaped curve. He also observed that there was significant difference in the number of prey consumed on the two types of arena, more prey was consumed on paper than on leaf, for which he concluded that the increased movement and contact on the paper was responsible. On the leaves due to presence of leaf hairs, veins and midrib there was lesser physical contact owing to lesser movement. Mori and Chant (1966) reported that the functional response of *Phytoseiulus persimilis* to be better than that of *A. longispinosus.*

Ezulike and Emehute (1984) studied the functional response of *Amblyseius fustis* to increasing density of its prey *Mononychellus tanajoa.* The experiment was conducted in the laboratory at a temperature of 24 - 29°C and relative humidity of 50 - 73 per cent. In tests of eight densities of prey (10, 20, 30, 40, 50, 60, 70 and 80 nymphs and adults), the consumption of prey by the predator increased up to a density of 40. The number of eggs laid by the predator was not influenced by prey density. The functional response curve is typical of invertebrate predators. Akimov and Kolodochka (1986) reported that *A. longispinosus* during it's oviposition period destroyed an average of 655 eggs or 90 deutonymphs of *T. urticae.*

Kim and Lee (1993) studied the functional response of *Amblyseius* (*Neoseiulus*) *longispinosus* to egg densities (10-80) of *Tetranychus urticae* under different egg distributions (clumped and uniform) and arena sizes (3, 9 and 16 cm^2). The searching success of *A.(N.) longispinosus* was affected by the spatial distribution and density of the prey, but not by the arena size. There was a highly significant negative correlation (r = -0.85 : P = 0.0001) between number consumed and distances between prey. The results showed a type II functional response. The random predator equation satisfactorily described *A.(N.) longispinosus* predation. The search rate ranged from 0.1030 to 0.1504 minutes when the prey followed clumped distribution, while it ranged from 0.0546 to 0.0276 when the prey were uniformly distributed.

Hegde and Patil (1995b) studied the feeding capacity of *A. longispinosus* on cotton red spider mite *Tetranychus macfarlanei* Baker and Pritchard and reported that feeding capacity of adult female *A. longispinosus* was 14.22 ± 0.66 eggs/day. All the stages of *A. longispinosus* preferred to feed on eggs of the prey. Other stages of the prey were also fed by the predator, but at very low numbers.

Mallik (1974) reported that the protonymphs, deutonymphs and adults of *A. longispinosus* consumed on an average of 3.0, 4.0 and 26.0 eggs of *T. ludeni* per day.

Manjunatha (1988) reported that all the stages of *A. longispinosus* preferred to feed on eggs on *Oligonychus indicus* Hirst. The immature stages of female fed on an average 20.71 eggs, 11.42 larvae, 6.6 nymphs, 2.7 adults/day. The immature stages of male fed on an average 7.8 eggs, 5.25 larvae, 1.20 nymphs and 0.2 adults per day. Adult females fed on an average 53 eggs while males fed on mean total 8 eggs per day . Adult females fed on an average 26.4 larvae, 24 nymphs, and 12.9 adults/day. Adult males fed on an average 3.0 eggs, 0.5 larvae and 0.7 nymphs and 0.2 adults of *O. indicus.*

Nakagawa (1985) reported that at 100% R.H and 20 and 25^0 C an adult female consumed on an average 10.44 and 15.88 eggs of *Tetranychus kanzawai* Kishida per day respectively.

2.2.1 Predator prey interaction

The role of phytoseiid mites in regulating spider mite population has been well documented (Huffaker *et al.*, 1970 ; McMurtry *et al.*, 1970). Chant (1959) reported that the predator population must increase as the prey population increase, to control the prey, otherwise the prey density is not checked.

Solomon (1949) considered prey density to be an important factor in determining the response of the predators. To distinguish the effect of prey on predator abundance and predation efficiency, he defined the functional and numerical responses. Functional response described the relationship between the number of prey consumed by an individual predator and prey density per unit of time. Numerical response describes the growth and death ratio of predator population as a function of prey density.

Holling (1959) described three types of functional responses. In type-I response the number of prey eaten rised linearly to a maximum. In type - II response as the prey density increased the number of prey eaten per predator also increased, but at a decreasing rate as the maximum value is reached. Thus there was decrease in prey mortality rate as its density increased. In type-III the mortality rate increased initially, but this rate gradually decreased and attained a plateau. This was called sigmoid functional response curve. The literature on functional responses of predatory mites has yielded type–VI and type-V responses. Type-VI response curve is dome shaped comprising of type-II curve and a drop in the number of prey eaten at high prey density levels, the type-V response which is reverse of type-VI shows a second rise in curve at high prey densities.

2.2.2 Interaction between Phytoseiid predators and their prey

Mallik (1974) reported that the interaction between *A. longispinosus* and *T. ludeni,* Zacher followed a definite trend. Irrespective of the ratios the prey population was observed to follow the same trend in laboratory and in field. In the initial stages (till 3rd day in 1:4 ratio and till 6th day in 1:100) there was an increase in the number of immature stages of the prey especially the eggs. Such proportionate increase was not observed near the peak. When the population started declining, reduction in the number of

immature stages was more pronounced than that of the adults. In predators, at 1:4 ratio a peak in their numbers was observed two days after the prey had reached the peak. When the population was declining the number of eggs of the predator was reducing, which was attributed to cannibalism or reduction in the number of eggs laid by the female due to lesser amount of food available. At 1:100 ratio he reported that the increase in predator number had reduced to half of its peak number. In the field highest ratio of 1: 5 (predator : prey) resulted in the elimination of the prey between first and second week of observation, but at 1:25, 1:20, 1:15 and 1:10 ratios such an elimination did not take place fast but was carried to ninth week of observation.

Manjunatha (1988) studied the interaction between *A. longispinosus* and *Oligonychus indicus* at five ratios (1:10, 1:20, 1:30, 1:40 and 1:50). Irrespective of the ratios, the predator assumed the proportion sufficient to counter the increasing prey population. Prey elimination from mileu was on 12th, 18th, 20th, 24th and 30th day at the above ratios, respectively. The decline in population of the prey corresponded with the appearance of the nymphs of the predator.

Sandness and McMurtry (1970) reported that among the three predators *A. largoensis* (Muma), *A. concordis* (Chant) and *T. floridanus* (Muma), *A. largoensis* and *A. concordis* consumed more *Oligonychus punicae* and the response was curvilinear. Such a rise was seen almost up to a predator prey ratio of 1:200. They observed that with increase in prey density, the number of contacts between the predator (*A. concordis)* and the prey increased, whereas, the time spent on each prey was less and further the number of times the predator returning to feed the same prey was less. *A. largoensis* and *A. concordis* were found to lay increasing number of eggs when prey density increased but this trend levelled-off after a certain point.

Laing and Osborn (1974) reported the effect of prey density on functional and numerical responses of *Amblyseius chilensis* (Dosse) that showed a curvilinear rise to a plateau (type-II response). *A. chilensis* was found to increase the number it killed from 6.2 mites per day at a prey density of 10 to approximately 13.5 mites per day at a prey density of 210. The numerical response increased rapidly from 1.6 eggs per day at a density of 10 mites to a gradually rising plateau lying between 2.4 eggs at a prey density of

40 mites and 2.8 eggs per day at a prey of 210. They concluded that a dome shaped functional or numerical response did not occur in the phytoseiid-tetranychid interaction.

Santos (1975) studied the functional and numerical response of *Amblyseius fallacis* (Garman) to three stages of *T. urticae.* There was a linear relationship between density and number of prey eaten per predator up to 40 eggs per leaf when the prey was male and response was linear only up to 40 per leaf though the feeding rate of the predator increased up to a density of 200 per leaf. This was attributed to a stimulation interference component causing the prey to interfere with the normal activity pattern of the predator which was not observed with the eggs as prey. The functional response curve was dome shaped when female were the prey which was the result of switching over from females to eggs at higher prey density. The numerical response was found to increase and level off at a point before maximum number of kills.

Nelson (1973) reported that with increase in the density of *Panonychus citri* (McGregor) from 1, 5, 10 to 20, the number of individuals preyed upon by *Amblyseius hibisci* (Chant) also increased from 1, 2.4, 3.2 to 6.4 respectively.

Zhou *et al.* (1988) observed that the functional response of *Amblyseius nicholse* Ehara and Lee to *P. citri* could be described by type-II response and the searching efficiency and handling time increased with the age of the *P. citri* but were reduced as the diversity of the habitat increased.

Hariyappa and Kulkarni (1989) observed interactions between *Amblyseius ovalis* (Evans) and its prey, *Polyphagotarsonemus latus* (Banks) at ratios of 1:25, 1:50, 1: 100, and 1:150 *Amblyseius ovalis* eliminated *P. latus* on 9th, 12th and 17th day at the ratios 1:25, 1:50, 1:100 respectively. But the predators could not check the population of *P. latus* at 1:150 ratio. The decline in population of the prey was more rapid when the nymphs of the predator started appearing.

Anil (1990) studied the interactions between *A. longispinosus* and *O. indicus* at ratios of 1:5, 1:10, 1:20, 1:30. He observed that irrespective of the ratios the predator assumed proportions sufficient to counter the increasing prey population. Prey elimination

from the mileu was on 11th, 13th, 13th, 13th day at the above ratios, respectively. Observations on interactions at 1:40 ratio was not continued after the 13 days since areca leaves used had turned yellow.

2.3 Dispersal ability of Phytoseiid predators:

Van de Vrie (1985) Studied the dispersal of *Phytoseiulus persimilis* on chrysanthemum under different conditions of prey density. It was found that *P. persimilis* spreads very rapidly on young plants when the leaves form a closed canopy. Distances of 15 m. along the beds within 1 week were an exception. Also dispersal across the path between the beds was with in 1 week which is remarkably fast. Dispersal up to 10 m. was registered, because these mites are one of the most agile and active phytoseiids, this result may well serve to indicate the maximum dispersal by locomotion.

Johnson and Croft (1981) reported that *A. fallacis* and *T. occidentalis* (Nesbitt) are aerial planktons, and trapped them on greased plates even at considerable distances from the orchard inhabited by predatory mites.

Hoy (1982) released an OP-carbaryl resistant strain of *T. occidentalis* at one spot in a large almond orchard. After one year OP-carbaryl resistant predators were found throughout the 32 ha almond orchard. She also reported that all the predators trapped on sticky panels were females, no males or immature were recorded.

Johnson and Croft (1981) reported that most predators trapped were adult females (53%), but males (18%) and immatures (29%) were also captured and also reported that the number of predators trapped inside an apple orchard at 4, 8, 19, 42 and 72 m from the border decreased exponentially. They concluded that predators could disperse over 72 m during one month period.

Hoy *et al.* (1982) reported that predators were trapped on greased plates at 200 m. distance from an almond orchard and also reported that dispersal distances is determined by turbulent air movement and convection.

Johnson and Croft (1981) conducted wind tunnel experiments. According to their findings, wind speed should exceed 0.5 m/sec. for the predators to take-off. Hoy *et al.* (1985) observed that most aerial movement occurred between 16.00 and 22.00 hr, when relative humidity and wind speed increased and temperature decreased. Johnson and Croft (1981) reported that when prey in apple trees became limiting to predators reproduction, dispersal of the predators by air current and *via* the trunks into the ground cover increased there by increasing the predator density in the weeds beneath the trees. Sabelis and Afman (1984) reported that when *P. persimilis* was starved for one day at 25^0 C approximately 75 per cent females dispersed from a leaf in a wind tunnel.

Coop and Croft (1995) conducted an experiment in three separate tests in Oregon, 100 adult females *Neoseiulus fallacis* (plus immatures) were released at five points across 1.6 m. rows of strawberries to control *T. urticae.* Beginning in April for 6-12 weeks predators controlled pests locally and dispersed down wind upto 20-30 m. About 100 m^2 around each release point was colonized and the entire 2.5 ha field was covered by predators by September. Distance to which *N. fallacis* had dispersed was similar within and across rows suggesting that dispersal was primarily by aerial rather than by ambulatory means. Factors that affected dispersal were temperature, wind direction density of *T. urticae,* and mowing and flailing of foliage. An exponential model of dispersal was fitted to the data, on an average, the area covered by *N. fallacis* doubled every 70 degree days. From these results a strategy of minimum release was suggested. To establish *N. fallacis* over a field in a single season approximately 100 adult females per 1-2 m. row can be released before 1^{st} July after *T. urticae* has reached the density of 2-5 females per leaf. Release should be 50 m apart and to the upwind side of the field. Selective sprays may be needed to suppress the *T. urticae* until the predator gains control and disperses over the field.

Scopes and Stacey (1977), reported the spreading of *P. persimilis* in *T. urticae* infested chrysanthemum. One predator per ten plants gave complete control of spider mites. Predators dispersed up to a distance of 15 m. along the bed within one week.

2.4 Management of spider mites :

2.4.1 Field release of different species of phytoseiid predators

2.4.1.1 *Amblyseius aberrans* (Oudemans)

Duso (1989) reported the use of *Amblyseius aberrans* against *Panonychus ulmi* and *Eotetranychus carpini* on apple in Italy. *Amblyseius aberrans* was able to keep the spider mite populations at low levels in two experiments.

2.4.1.2 *Amblyseius andersoni* (Chant)

Vilajellu *et al.* (1994) studied the effectiveness of *Amblyseius andersoni* (Chant) on *Panonychus ulmi* in apple. Successful biological control of *P. ulmi* was achieved by the predator. A simple management strategy was proposed based on time of sampling, per cent leaves with *P. ulmi* and per cent leaves with phytoseiids.

2.4.1.3 *Amblyseius idaeus*

Populations of the phytoseiid *Amblyseius idaeus* from north-eastern Brazil were released in Benin during 1989-90, for the control of the tetranychid *Mononychellus tanojoa* on cassava by Yaninek *et al.* (1991). Monthly follow-up surveys revealed the presence of *A. idaeus* at most release sites. Some populations persisted for at least 18 months in 2 cycles of potentially limiting wet and dry seasons. At some sites *A. idaeus* was the numerically dominant phytoseiid predator on cassava, where it was associated with *M. tanojoa* and *Oligonychus gossypii.* During periods of low *M. tanojoa* densities *A. idaeus* disappeared from cassava but was found on weeds with *O. gossypii,* until prey densities on cassava increased.

2.4.1.4 *Amblyseius limonicus* Garman

Braun *et al.* (1987) reported the effect of *A. limonicus* on *Mononychellus progresivus* and *T. urticae* on cassava. Doses for field testing were chosen based on laboratory data, plots that received bimonthly permethrin treatment with either 2 or 8 g.a.i./100 litre had significantly lower numbers of *A. limonicus* than untreated plots.

M. progresivus number began to increase in treated plots immediately after initiation of permethrin applications and remained significantly higher than in untreated plots.

2.4.1.5 *Amblyseius longispinosus* (Evans)

Ganok (1982) reported that longevity of females of *A. longispinosus* was much higher than *T. truncatus* Ehara females. The best relationship was obtained when the initial ratio of *T. truncatus* female to *A. longispinosus* female was 5:3 temperature, relative humidity and day length had no effect on both species of mites.

Kongchuensin *et al.* (1998) studied the effectiveness of *A. longispinosus* on *T. urticae* in a strawberry field in Thailand, 2, 5 and 10 predators per plant were released, when *T. urticae* number was five mites per leaflet. Spider mite population was significantly reduced within 4 weeks after releasing the predator two times. Mass releases were made at two weeks intervals at the rates of 2-5 predators per plant seven times. Spider mite populations was 172.64 mites per leaflet in the check but 57.86 mites per leaflet in the released plot.

Onkarappa (1999) reported that *A. longispinosus* caused maximum reduction of tetranychid (*T. urticae*) population when released at a ratio of 1:300 compared to 1:450 and 1:900. Reduction in number of tetranychid eggs was high compared to nymphs and adults. Good control of tetranychid mites was achieved twentyone days after release of predators. Predators spread to the predator free plants. When the prey mite was exhausted on the predator released plants.

2.4.1.6 *Metaseiulus occidentalis* (Nesbitt)

Hoy (1985) reported that carbaryl - OP resistant strains of *Metaseiulus occidentalis* was released at the rate of 350 females for every third tree of almond in every third row. Predator survived and eventually controlled tetranychid mites even after carbaryl sprays to control twig borer and naval orange worm.

Wilson *et al.* (1983) showed that 1:10 *M. occidentalis* to *Tetranychus* sp. gave good control within two weeks. Coop and Croft (1995) reported that release of 100 adult females of *Neoseiulus fallacis* per 1-2 metre row of strawberry infested with *T. urticae* and selective sprays gave good control.

2.4.1.7 *Phytoseiulus persimilis* (Athias-Henriot)

Kilincer *et al.* (1992) reported that release of 15, 16, 20 and 40 *Phytoseiulus persimilis* per plant on gerbera, tomatos, carnation and rose respectively suppressed *Tetranychus* sp. population. Vacante (1985) reported that in Sicily, on melon, chilli, strawberry and rose, under protected cultivation, when the pest (*Tetranychus urticae*) density was not more than 10-15 mites per leaflet at timely release of predator *P. persimilis* the rate of one predator to ten prey gave complete control.

Workman and Martin (1985) reported the use of both chemicals and predators to control *T. urticae* on strawberry. Azinphosphmethyl and pirimicarb were sprayed at 14 days interval until 18th January. Predators (*P. persimilis*) released on 29th February, controlled the tetranychid population at low levels throughout the season without the need for further acaricide applications.

Parr and Hussey (1969) reported that successful control of spider mites (*T. urticae)* was achieved within six weeks following the introduction of single predator (*P. persimilis)* on to alternate plants after every plant was harbouring twenty female *T. urticae.*

Hart (1987) studied the effectiveness of the predatory mite *P. persimilis* in controlling *T. urticae* in out door ornamental plants in a commercial plant nursery near Sydney. Four thousand potted plants were evenly divided into two "release" treatment blocks and two "non-release" control blocks approximately 10,000 *P. persimilis* were uniformly distributed in each of the release blocks into the existing *T. urticae* infestations, 100 leaves were sampled from each block. In release blocks, *T. urticae* levels decreased from an initial mean score of 1.95 to 0.09 in eight weeks. In non- release blocks *T. urticae* levels increased from an initial mean score of 1.90 to a maximum of 2.64.

Nicoli and Benuzzi (1988) reported the biological control of *T. urticae* (Koch) with *P. persimilis* on cucumber grown in glass houses in Northern Italy. The introduction of *P. persimilis* was studied both in spring and summer in seven greenhouses. During the summer cultivation (0.1 - 0.5 *T. urticae*/leaf), release of the predator at 5-8 *P. persimilis* per m^2 equal to 1.2- 2.4 *P. persimilis* per plant provides good control. During spring (0.01 – 0.10 *T. urticae* per leaflet), early releases are very low as the pest may develop towards the end of the cycle. In all cases *P. persimilis* has proved capable of controlling *T. urticae* in the top part of the plant.

Nihoul and Van-Impe (1991) studied the control of *T. urticae* using *P. persimilis* in tomato crops under glass in Belgium. Two experimental greenhouses with tomato crops were subdivided into two compartments. The predatory mite *P. permilis* was released in one compartment and acaricides were used in the other; the crops were observed for 28 and 39 weeks. In the biological control compartment, weekly release of 25000 predators/100 m^2 were made for the 28-week crop, and in the 39 week crop 36,300 predators/100 m^2 were released at intervals of 2-9 weeks. Less repeated introductions were apparently possible because of more favorable conditions of temperature and RH for both crops, no differences were found in tomato production between the biological and chemical control compartments, although there was a gradual increase in the tetranychid population due to an unstable predator-prey ratio.

In a study by El-Lathy (1992) in spring the predator *P. persimilis* was released early on plants infested with *T. urticae* in one green house at 10 predators per plant and again at the same rate 3 weeks later; in another greenhouse the release was at 15/plant. The population density of the prey in the first greenhouse reached 39-48 mites/$inches^2$ and integration with acaricides was necessary. The population in the second green house reached 35 mites/$inches^2$ and then declined gradually to 22.1 without the application of acaricides. Generally *P. persimilis* was not effective in reducing tetranychid infestation below the economic threshold. Factors that may have been responsible were the low relative humidity (22-68%), fluctuating temperature. Problems with rearing, storing the predators, and the stage of growth of the cucumber plants on which they were released.

Ashihara *et al.* (1992) reported that in 25 out of 30 phytoseiid predators (*P. persimilis)* released plots, population of *T. kanzawai* decreased faster than in the plots where phytoseiids were not released, of the 30 plots the release was considered to be effective or highly effective in 20 plots.

Hirschberger and Kremheller (1993) studied the control of *Tetranychus urticae* using *P. persimilis* at 3 locations in Germany. The predatory mite was very susceptible to fluctuations in temperature and humidity and reproductive rates were much lower than those of *T. urticae,* satisfactory control was not achieved.

Wood *et al.* (1994) studied the biological control of two-spotted spider mites in field raspberries using the predatory mite *P. persimilis* at Agassiz, British Columbia. For 8 weeks after release the numbers of *T. urticae* were consistently lower in the treatment plots than in the control, being significantly different on two dates.

Hance *et al.* (1991) compared the efficacy of a chemical control technique and a biological control technique for the protection of tomato against the spider mite *Tetranychus urticae*. For biological control, *P. persimilis* and *A. andersoni* was used. For the test of chemical control, hexythiazox (5g.a.i /100m^2)was applied. Leaf damage was monitored weekly increase in damage in the green house under biological control regime prompted the introduction of more predatory mites. By the end of the season, there were no significant differences in yield or fruit size between the two regimes. Gross income from the biological control regime was greater.

2.4.2 Management using Chemicals

Literature on abamectin, profenofos and dicofol tested against tetranychid mites are presented in Table 1

Table 1 : Pesticides screened against tetranychid mites on various crops

Sl. No.	Pesticides	Concentrations	Tetranychid species	Host	Remarks	References
1	Abamectin	20 ml/100 litres	*Tetranychus urticae*	Rose	Effective	Aguiar *et al.* (1993)
	-" -	4.5 ppm	*T. urticae*	Rose	6000 l/ha spray solution gave good control	Green *et al.* (1985)
	-" -	0.45g/100 liters	*T. urticae*	Ornamental Crops	Effective	Green and Dybas (1984)
	-" -	1.5 litre/ha	*T. urticae*	Strawberry	Effective	Masis and Aguilar (1990)
	-" -	10.8 g.a.i/ha	*T. urticae*	Cotton	Effective	Ramalho *et al.* (1986)
	-" -	10.8 g.a.i/ha	*T. urticae*	Cotton	Observed development of resistance.	Clark *et al.* (1995)
	-" -	5-27 g/ha	Phytophagous mite	Citrus, Cotton, Pear & vegetables	Effective	Lasota and Dybas (1990)
	-" -	0.00036%	*T. urticae*	Rose	Good	Onkarappa (1999)
2	Dicofol	0.04%	*Eutetranychus orientalis*	Almond	Effective control (93%) after 5 days	Dhooria and Sandhu (1973)
	-" -	0.075%	*Eu. orientalis*	Citrus	Highly effective (100%) after 2 days	Dhooria and Butani (1982)
	-" -	0.0025%	*Eu. orientalis*	Citrus	Effective after 2 days	Deshpande *et al.* (1988)
	-" -	0.02%	*Oligonychus indicus*	Sorghum	Less effective	Mital *et al.* (1981)
	-" -	0.03%	*O. indicus*	Sorghum	Good Control (84%) after 3 days	Patel *et al.* (1989)
	-" -	0.25%	*Tetranychus cinnabarinus*	Alfalfa	Reduced the population after 2 sprays	Osman and Rasmy (1981)
	-" -	0.03%	*T. cinnabarinus*	Cassava	Not Effective	Lal and Pillai (1984)

	-" -	0.1%	*T. cinnabarinus*	Groundunt	Effective	Osman and Rasmy (1976)
	-" -	2 ml / l	*T. cinnabarinus*	Jasmine	Good control after 2 weeks	Karuppuchamy *et al.* (1986)
	-" -	0.025%	*Tetranychus cucurbitae*	Brinjal	Good control after 3days (85%)	Singh *et al.* (1975)
	-" -	0.01%	*Tetranychus ludeni*	Okra	One application 50 days after sowing gave good control.	Nangia and Channabasavanna (1983)
	-" -	0.03%	*T. ludeni*	Redgram	Moderate control (73%) after one day.	Shah *et al.* (1989)
	-" -	0.05%	*Tetranychus macfarlanei* Baker and Pritchard	Okra	Good Control (84%) after 1 day	Patel *et al.* (1993)
	-" -	0.03%	*Tetranychus neocaledonicus*	Cassava	Not Effective	Lal and Pillai (1984)
	-" -	0.1%	*T. neocaledonicus*	Mulberry	Not Effective	Pillai and Jolly (1986)
	-" -	0.5 Kg/ha	*T. neocaledonicus*	Okra	Not Effective	Jaganmohan and Krishnaiah (1981)
	-" -	370.g.a.i./ha	*Tetranychus* sp.	Cotton	Effective	Murega and Khaemba (1985)
	-" -	0.03%	*Tetranychus telarius*	Brinjal	Moderate control (71%) after 2 days.	Shah *et al.* (1989)
	-" -	0.04%	*T. telarius*	Okra	Effective control (100%) after one day	Palanisamy and Subramaniam (1977a)
	-" -	0.25%	*T. urticae*	Alfalfa	Reduced the mite population after 2 sprays	Osman and Rasmy (1981)
	-" -	400/100 gallon	*T. urticae*	Apple	Not Effective	Asquith (1968)
	-" -	1000 ml/ha	*T. urticae*	Beans	Good control	Askari and Zare (1976)

	-" -	0.031%	*T. urticae*	Brinjal	Effective control (100%) after 3 days	Basu and Pramanik (1968)
	-" -	0.052%	*T. urticae*	Chrysanthemum	Good control of eggs	Baranowski (1976)
	-" -	0.03%	*T. urticae*	Cotton	Good control (84%)after 3 days	Patel *et al.* (1988)
	-" -	500 g.a.i./ha	*T. urticae*	Cotton	Good control	Ramalho *et al.* (1986)
	-" -	0.2%	*T. urticae*	Hops	Effective Control	Vostrel (1993)
	-" -	0.0625%	*T. urticae*	Melon	Effective control (93%)	Atalla *et al.* (1970)
	-" -	0.04%	*T. urticae*	Okra	Very good ovicidal effect (85%)	Palanisamy and Subramaniam (1977b)
	-" -	0.2%	*T. urticae*	Ornamental Crops	Good control	Szekely *et al.* (1976)
	-" -	250ml/100 litres	*T. urticae*	Peach	Good control	Nassar *et al.* (1984)
	-" -	1.12 kg/ha	*T. urticae*	Peanut	Effective control after 3 sprays	Smith and Mozingo (1983)
	-" -	0.05%	*T. urticae*	Rose	Less effective	Pokharkar *et al.* (1986)
	-" -	0.2%	*T. urticae*	Rose	Dipping plants for 3 minutes gave good control.	Bogs and Brasch (1985)
	-" -	0.2%	*T. urticae*	Strawberry	Effective control	Atanasov (1983)
	-" -	0.044%	*T. urticae*	Rose	Effective in few polyhouses and less effective in other poly houses.	Onkarappa (1999)
3	Profenofos	500 g.a.i./ha	*Tetranychus* sp.	Cotton	Moderate control	Murega and Khaemba (1985)
	-" -	0.0125%	*T. urticae*	Rose	Good control	Onkarappa (1999)

2.5 Mass production of Phytoseiid predators :

2.5.1 Rearing on artificial Substrates

A simple and very useful device for mass rearing phytoseiid mites was developed by McMurtry and Scriven (1965). The rearing unit consisted of a 15 X 15 cm construction paper sprayed with black paint and laid on a 1.5 cm thick 16 X 16 foam plastic saturated with water. The foam plastic was placed in a 20 X 20 cm cake pan filled with water. Strips of wet tissues were stretched round the periphery of the construction paper which served as a barrier to discourage escape of the mites and also as a drinking water source. The above device was improved by the same workers in 1975, where they used a metal tile instead of the construction paper and reduced the size of the arena to make it easier for observation under a microscope. Tetranychid mites or pollen, were added to the arena. When prey was fed tetranychids, either teranychid infested leaves were laid on the substrate or the prey was brushed off the leaves on the arena. When prey was brushed or pollen added, cover slips were laid on strands of cotton or cotton strands alone were placed on the substrate to serve as oviposition sites for phytoseiid mites. Amano and Chant (1977) recommended the culturing of phytoseiid mites along with their prey. This consists of a detached leaf pressed on a wad of wet cotton wool in a Petri dish with water. A modification of this unit was described by Overmeer *et al.* (1982), who used a 8 X 15 cm^2 plastic tile, 5 mm thick which because of its smaller size was easier to examine under microscope and a thicker piece of foam plastic (3 cm) which can hold more water. The size of the foam plastic was equal to that of the tile. Short strips of tissue paper, 7 cm wide were stretched along the 4 edges of the tile, and folded over the edges in such a way that about 1.5 cm of the periphery of the tile was covered by the tissue paper and rest of the paper was hanging down in water which ensured the tissue paper remained wet. On the tissue paper, just above the edges of the tile, an extra barrier was added which consisted of a rectangle of sticky material. The wet tissue paper diminished the spread of the mites considerably and when a mite touched the sticky material it would turn round and move back to the plastic substrate to find food and shelter. Food was added to the arena as described above.

Ball (1980) developed an arena similar to the system described above. Mites were confined to a circle of black plastic with a diameter of approximately 10 cm, a thin piece

of plastic foil was laid on saturated cotton wool, in a plastic Petri dish of 15 cm diameter. On the circle a detached lima bean leaf *(Phaseolus limensis)* infested with the prey was placed, ventral surface down with the petiole in the wet cotton wool to keep it fresh.

Kumburov (1966) and Swirski *et al.* (1967) developed an arena with a different barrier. The arena consisted of a 10 X 10 cm black plastic tile of 4mm thickness, in which an 8 cm diameter ring shaped 2 mm wide gutter was cut. The gutter was filled with a mixture of machine oil or castor oil or vaseline. In the middle of the arena a wick was pulled through a hole, this provided the mites with drinking water. The arena was placed on a wet sponge. A number of concentric ridges carved on the surface of the arena would diminish the speed.

Krishnamoorthy (1982) developed a rearing unit for *Amblyseius tetranychivorus* in which a wooden platform is kept in the center of an aluminum pan. A glass plate is kept over the platform in such a way that the painted surface faced down to form a good back ground for observation. A strip of wet cotton is kept all around the glass plate to prevent predatory mites from escaping. Sufficient water is maintained in the tank to keep the cotton strip saturated and maintain high relative humidity (85-88%). Castor pollen grains were used to rear *Amblyseius tetranychivorus* which readily accepted the pollen grains, fed voraciously and laid eggs on the cotton wool strands provided. Pollen grains were provided once in two days and approximately 4mg were required for about 500 adult mites.

Zhang and Li (1989) reported that rearing of *A. fallacis* with apple pollen and providing *T. cinnabarinus* at an interval of 6 to 7 days proved to be a better method than those involving honey solution or royal jelly. Herron *et al.* (1993) reared the predator, *Euseius scutalis* on castor pollen. In addition to pollen grains and nectar, predators were observed feeding on plant sap from veins. High number of predators in a confined place induces cannibalism. Removing the egg masses daily from the culture saved many immatures. Adding immatures of the phytophagous mite, *T. cinnabarinus* to the culture decreased the cannibalistic behaviour.

2.5.2 Rearing on detached leaf cultures

This culturing method consists of a detached leaf pressed on a wad of wet cotton wool, contained in a small dish with water. Spider mites flourish well on such leaves. Some species of phytoseiids could be reared easily together with their prey on detached leaf culture. Most suitable plants for detached leaf cultures are the plants with leaves which last relatively longer in such a condition, e.g., different kinds of beans such as *Phaseolus vulgaris, P. limensis* and *Ricinus communis* L. *P. persimilis* develop very well on leaves with *Tetranychus pacificus* McGregor, (Amano and Chant, 1977) and *T. urticae* as prey (Van Zon and Wysoki, 1978).

T. occidentalis (Tanigoshi and Brown 1978) and *Amblyseius bibens* Blommers (Blommers, 1976) developed well on bean leaves with *Tetranychus* sp. *P. persimilis* could be reared successfully on detached leaves of chinese taro, *Alocasia cacullata* (Lour) Schott infested with *Tetranychus tumidus* Banks (Prasad, 1967).

McMurtry and Scriven (1965) reported that *Amblyseius hibisci* was reared satisfactorily on detached avacado leaves on moist cotton. This was mainly because it needs to extract juices from the leaf. Karuppuchamy *et al.* (1988) developed a mass rearing unit which consisted of a glass or metal tray (20 cm diameter and 10 cm height) a glass vial and a small tube (preferably a used ball pen refill). A small hole was made in the stopper of the glass vial and about 2.5 cm of the refill was inserted through the hole leaving the leaf lamina outside. The glass vial was filled with water and closed with the stopper. The glass vial was kept horizontally in a petridish (15cm diameter) blackened on the outer surface. The petridish with glass vial was kept inside a glass or metal tray and water was added to 0.05 cm height. in the outer tray and the whole setup was covered with a glass plate. A known number of the predatory mite *P. persimilis* was reared, *T. cinnabarinus* the prey was provided once in three or four days. The glass vial was filled with water once in ten days, when necessary the leaf was also changed. They reported that multiplication of phytoseiids was faster compared to those reared on arena described by others.

Anil (1990) reported three methods of rearing the phytoseiid *A. longispinosus,* on detached leaf cultures. In the first method of mass production the petiole of a trifoliate bean leaf infested with *T. macfarlanei* were inserted into stoppered vials filled with water and placed over an arena formed by blackened glass plate. The second method was similar to the above except that the usage of vials was avoided by sandwiching the petiole between the cotton strips bordering the arena. In the third method, sorghum leaf strips with mostly eggs and immatures of *Oligonychus indicus* were provided to the predator on a similar arena. Supplementing prey, production and harvesting of the predator was more efficient in the methods where beans leaf was used.

2.5.3 Rearing of phytoseiids in cages

Munger (1942) developed a phytoseiid rearing unit called munger cell. It consisted of a 5 X 8 cm X 1 cm thick plexiglass with a circular 3 cm diameter hole in the center. This is enclosed within two glass plates, of similar size which formed the top and bottom of the cell. Between the bottom glass and the plexiglass a bean leaf was placed on 3 layers of 5 X 8 cm^2 pieces of filter paper in such a way that the leaf substrate formed the bottom of the inner side of the cage. The lower most piece of the filter paper was soaked in water. Prey was placed in the cell followed by predators by shifting the top glass plate aside to make a small opening. The cell was closed by placing the top glass plate precisely on the piece of the plexiglass and the whole unit was held together by wrapping sticky tape around the cell. This prevented desiccation and possible escape of the mites (Huffaker, 1948).

Tanigoshi *et al.* (1975) developed a rearing cage for phytoseiid predators. This rearing unit was constructed from two cardboard ice cream cartons, 4.5 cm height and 8.5 cm in diameter. The bottoms of the cartons were removed and a piece of fibre glass window-screen fitted between the cartons. The cartons were taped together bottom to bottom. In each of the 2 lids of the ice-cream cartons a hole of 2.5 cm diameter was cut and covered with parachute cloth. Lima beans infested with spider mites were placed within the upper chamber of the rearing unit and this chamber was subsequently inoculated with the predator. After 3 days the unit was inverted and a fresh supply of infested lima

bean leaves were placed in the upper chamber. The old leaves in the lower chamber were later discarded.

2.5.4 Large scale rearing of phytoseiids

Scriven and McMurtry (1971) reported large scale multiplication of phytoseiids. Lima bean (*Phaseolus limensis)* seedling held 7 days after planting at 27.2°c under fluorescent lights, were transferred to a green house and infested with 0.24 grams of *Tetranychus pacificus* eggs per 100 plants. After 14 days the mites present on the leaves were washed in a washer. The washer consisted of plastic resin coated plywood box with a capacity of 205 lt. This was fitted with a water overflow, a valve controlled drain, water supply valve and air jets in the bottom. The bean foliage was harvested and placed in the washer which was nearly filled with water, 2 liters of standard bleach solution (5% Nacl) and 0.4 ml of liquid detergent were added. Air from the bottom of the container at a pressure of 50 lb/sq. inch agitated the water and bean leaves and removed the mites from the leaves. After 20 minutes of agitation, water was drained into a separator. The separator consisted of 5 plastic pots, the bottom of each pot was replaced with different grade of fine metal screen. These different sized screens trapped eggs, immatures and adults mites, these mites which collected on the screen were washed and dried. Recovery of mites during 8 week period averaged 1.29 grams or about 3,53,860 mites per hundred seedling. Weekly production from 5000 plants averaged 64.4 g of mites and required about 12 man hours per week for the entire process.

Friese *et al.* (1987) reported that the eggs of *Mononychellus tanajoa* and *T. urticae* were harvested using brushing machine or water based mite separator unit. Stock maintenance cultures were initiated at regular intervals to have a definite productive period and used as a source for mass rearing of phytoseiids.

Koppert (1980) studied the large scale rearing of phytoseiids for spider mite control in cucumber. Mass rearing of *P. persimilis* for release purpose was carried out on bean plants infested with spider mites in a green house, large number of plants were grown, which were subsequently inoculated with *T. urticae,* as soon as distinct spider mites aggregations were found and damage to the plant was imminent, the predaceous mites

were distributed over the plants, the offsprings of the introduced predators were harvested and sold to growers for release in commercial holdings.

Hoy *et al.* (1982a) explained a method for large scale rearing of *Typhlodromus occidentalis* (Nesbitt) on *T. urticae* in a 45 m^2 green house, *T. urticae* was mass reared on bean plants in 35 X 28 X 55 cm flats, old stock flats containing only *T. urticae* were cut and distributed over new foliage, the spider mites moved off from cut leaves to recipient plants. The dried leaves were removed after 2-3 days. A mature bean flat containing *T. urticae* could infest 4 to 8 new flats . Flats planted and infested every 2 to 3 days provided continuous spider mite production. These plants were used for producing pure colonies of *T. urticae* as prey for predator and also for producing *T. urticae* to augment prey populations. In mixed flats, predator prey ratios were monitored. The mites were collected using a mite brushing machine and counted under dissecting microscope. When very few spider mites (less than 20 spider mite to one predator) were present, flats with *T. urticae* only were cut and placed on the mixed flat to augment the prey population. If too many spider mites were present (more than 50 spider mites to one predator), a low concentration of propargite (0.33 – 0.66 g 30 wp omite/l of water) was sprayed. Ideal spider mite and the predator ratios were between 20 and 40 spider mites to one predator for unlimited growth of predator populations. The flats were sprayed with carbaryl (3.0 g 80 WP. sevin/1lit. of water), permethrin (0.5 g.a.i 0.2 EC) or sulfur (6.3 g 90 s orthoflotox/1 water) on established flats or new flats to control the contaminating phytoseiids. The total labour required for planting watering, spraying, sampling and counting was estimated to be 11.08 man hours for 24 flats, over the 42 days intervals. Optional tasks, such as spraying or adding prey required, 0.8 to 3.8 man hours of labour. The ideal time for harvesting the flats was shortly before 4 weeks after infestation.

Hegde and Patil (1995a) reported the mass multiplication of the predator *A. longispinosus* on potted cotton (MCU-5) plants containing cotton red spider mite. *T. macfarlanei.* Gravid females of *A. longispinosus* were released at densities of 1, 2, 3, 4 and 5 pairs per plant and count was made 10 days after release of the predator. A total number of 4, 7, 12, 15 and 20 predators were recorded from initial 1, 2, 3, 4 and 5 pairs per plant respectively.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The laboratory studies were conducted in the Acarology laboratory, Department of Entomology, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bangalore. Field studies were carried out at TransIndia Floritech, Doddaballapur between September 1997-August 1999.

3.1 Sampling :

The study on sampling was conducted at TransIndia Floritech, Doddaballapur. FirstRed was the variety of rose selected, which was grown in one hectare area in one of the polyhouses. Fifty plants were randomly selected from one hectare area. Each plant was labeled so also the various canopy levels, *viz.,* bottom, middle and top canopy. Average plant height was 1.5 m top 0.5 m was labelled as top canopy, middle 0.5 m as middle canopy and bottom 0.5 m as bottom canopy. From each canopy levels three compound leaves were collected randomly, labelled and placed in separate polythene covers and brought to the laboratory. A compound leaf of rose consists of five leaflets, the terminal leaflet was named ' T ', first left leaflet from the top as ' L1 ' and second left leaflet as ' L2 ', while first right leaflet as ' R1' and second right leaflet as ' R2 ' . The leaves were observed under stereobinocular microscope, the eggs, nymphs and adults of *Tetranychus urticae* on each of these leaflets were counted and recorded.

The data so obtained were utilized to study the distribution pattern of *T. urticae* on different canopy levels of the plant. The population of the mites on different leaflets and leaves were correlated with total population. Mean and variance was calculated for eggs, nymphs and adults of *T. urticae* with different canopy levels of the plant (Southwood, 1978).

3.2 Functional response and numerical response of *Amblyseius longispinosus* :

An arena of 5 x 5 cm mulberry leaf was used for the study. The leaf bits were placed on wet cotton in petridishes (9 cm diameter) with their lower surface upwards.

Twenty females of *T. urticae* were released on each leaf bit and 24-48 hrs later the females were all taken off the leaf bits after they had laid sufficient eggs. Sixtyfive such bits were used for each treatment, and on all these the number of eggs as required by the particular treatment was retained and excessive eggs were picked and destroyed. Sixtyfive bits were required for each treatment since only five bits were used for each observation which was taken after a period of two hrs. One adult female *A. longispinosus* (two days old) was released on each of these leaf bits. The predators were taken from a laboratory culture with individuals of approximately same age. The number of prey eggs fed, or eggs laid by the predator during the first two hrs of the study was not considered in order to ensure that the predators were brought to the same satiation level at the start of the study. The observations were recorded once every two hours (twelve observations per day). The female predators after every two hours were transferred to a new set of leaf bits having the same number of eggs. In order to ensure that the females were transferred to the next set, with least disturbance a loop made out of a needle was used. The number of prey eggs devoured and number of eggs laid by the predator on each of these bits exposed to the predator for two hours was recorded and cumulative total for the twenty four hours period was used for the analysis. The treatments were 10, 20, 30, 40, 50, 60, 70 and 80 eggs per leaf bit and each treatment was replicated five times. After every two hours the number of prey eggs consumed and the number of eggs deposited by the predator were recorded. This study was conducted at room temperatures 24-26^0 C and 75 per cent relative humidity.

3.3 Dispersal ability of *Amblyseius longispinosus* :

The study was conducted at TransIndia Floritech, Doddaballapur. In one of the polyhouses one bed was selected for the study. The length of the bed was 40 mts. The average height of the plants was one metre. At the time of study the shoots had been bent to induce flower bud bursting. From the centre of the bed, where the predators were to be released, sampling points at 1 m, 3 m, 6 m and 10 m on either side were marked with labels. Before release of predators, leaf samples were collected, labelled and brought to the laboratory and observed under a stereobinocular microscope. Adult female *A. longispinosus* reared on French bean plants with *T. urticae* as prey in the glass house of Entomology Department were used for the study. The bean leaves were harvested brought

to the laboratory and number of predators present on the leaves were counted under stereobinocular microscope. These leaves with predators were transferred to the polyhouse in a cool container. Several bean leaves, which all together had 250 predatory mites, were placed on rose plants at the center of the bed. Every week after release of the predators 10 compound leaves of rose collected randomly from each sampling point and observed for both *T. urticae* and *A. longispinosus* under a stereobinocular microscope. The number of egg, nymph and adult stages of both prey and predator were recorded. The observations were recorded for 8 weeks after release of the predators.

The mean dispersal index for egg, nymph and adult stages of the predator was computed from :

$$\frac{\sum \{\text{Distance of the sampling point from the release point} \times \text{No. of predators at the sampling point}\}}{\text{Total number of predators at all sampling points.}}$$

3.4 Management of spider mites using phytoseiids :

3.4.1 Predator release

The study was carried out in a polyhouse of TransIndia Floritech Ltd., at Doddaballapur, north of Bangalore. The variety Sacha was selected for the study. Four rose beds each 40 M. long were selected. These four beds had uniform infest a ion of *T. urticae*. Before laying out the experiment, 50 leaflets from each bed were randomly collected, brought to the laboratory to record the number of different stages of *T. urticae.* The average number of mites per leaflet was calculated, this multiplied with total number of leaves present per plant and the total number of plants in three metres to obtain the total population of the prey mites in the experimental plots. Based on the population of spider mites in each plot the different ratios of predator - prey were fixed. Size of each plot was three metres and one metre gap was maintained between each plot.

The ten treatments (predator : prey ratio) were

1:40

1:80

1:160

1:200

1:400

1:600

1:800

1:1000

1:1200

Control (without predators)

The treatments were replicated four times. Treatments were randomized following RCBD. Fifty leaflets from each plot were sampled before release of predators and 4, 8, 12, 16, 20, 24, 28 and 32 days after release. Samples were collected in separate polythene covers, brought to laboratory and observed for egg, nymph and adult stages of both the prey and the predator. Data were analysed following ANOVA for Randomised Complete Block Design.

3.4.2 Management of spider mites using chemicals

To compare the effectiveness of the predators with that of chemicals in managing spider mites, a trial was conducted in the same polyhouse as above. Three beds of 40 m length with uniform infestation of mites were selected. Three chemicals were tested following RCBD. Each plot in a bed was 3M long consisting of 24 plants, 1 M gap was maintained between treatments. The chemicals were sprayed with a hand rocking sprayer. Water spray was used in control plots.

The treatments were :

Abamectin (Vertimec® 1.8 w/v) 0.2 ml/L (0.0003%)

Profenofos (Curacron® 50 EC) 0.4 ml/L of water (0.02%)

Dicofol (Kelthane® 18.5 EC) 0.75 ml/L of water (0.014%)

Control (Water spray)

From each plot 50 leaflets were collected before spraying and 1, 4, 8, 12, 16, 20 and 24 days after spraying and observed as mentioned above. The data were analysed following ANOVA for RCBD.

3.5 Mass production of *Amblyseius longispinosus* :

This study was conducted in the glass house of Department of Entomology. Here following two studies were conducted :

1) Development of *T. urticae* on French bean plants.
2) Mass multiplication of predators.

3.5.1 Development of *T. urticae* on French bean plants

French beans plants, variety Burfi-stingless, were used since it is a variety resistant to leaf rust. The seeds were sown in polythene covers (10 cm diameter), earthen thumb pots (14 cm diameter), earthen nand pots (22 cm diameter) and directly in the soil in a plot of $2m^2$. The pot mixture was prepared with red soil and farm yard manure (FYM), before filling the pot mixture was fumigated using formalin one per cent to kill the pathogens which cause collar rot of beans. After one week the pots were filled with the mixture and seeds were sown. In each pot one seedling was raised, 15 plants were used for the study, twelve days after sowing, the seedlings attained three compound leaves (nine leaflet) stage. This stage was selected to study the development of the spider mite. Three batches were maintained. In the first batch, twelve days after sowing bean seedlings in nine leaflet stage were infested with 3000 eggs, 2850 nymphs and 1900 adults of the spider mite. A total of 7750 spider mites of all stages were distributed on the 15 plants, uniformly. 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days after infestation with *T. urticae* 15 leaflets, one from each plant, were collected randomly and number of different stages of *T. urticae* was recorded. Total number of leaves present on the plants was also recorded. Later two more batches of French bean plants were raised similarly, the number of *T. urticae* infested were 3500 eggs, 2900 nymphs and 2000 adults ; 3400 eggs, 3000 nymphs and 2000 adults, respectively. The observations were recorded as mentioned above for the first batch of plants

3.5.2 Mass production of *Amblyseius longispinosus*

The study was conducted with four batches of French bean plants. In the first batch 12 days after sowing beans seeds in earthern pots, the seedlings were infested with approximately 3250 eggs, 3000 nymphs and 2000 adults of *T. urticae.* Nine days after infesting the plants with spider mites the plants were inoculated with 250 adult females of *A. longispinosus.* Fifteen leaflets were collected randomly, one from each plant, before release and 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days after release of predators, and the number of egg, nymph and adult stages of the prey and predator were recorded.

The same methodology was repeated for three more batches. But in these the same number of predators were released on the plants 12, 15, 18 days after the plants were infested with *T. urticae.* The observations were recorded for both the prey and predator as for the first batch.

3.5.3 Cost of production of predators

To estimate the cost of production of the predators, the components involved in its production like cost of earthern plots, beans seeds, farm yard manure, fertlizer, water, labour etc., were considered.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

4.1 Sampling of *Tetranychus urticae* :

4.1.1 Distribution of eggs, nymphs and adults of *Tetranychus urticae* on rose

The number of different stages of the mite was recorded from each leaflet of the leaf at three different canopy levels. All the three stages of the mite eggs, nymphs and adults, followed a similar pattern of distribution (Tables 2-4, Figs. 1-3). The leaves of middle canopy harboured more number of eggs, nymphs and adults followed by bottom canopy leaves and top canopy leaves. Within each leaf the terminal leaflet had significantly higher number of eggs, nymphs and adults followed by next pair of leaflets (L1/R1) and the least number were observed on bottom pair of leaflets (L2/R2). If the whole plant is considered, terminal leaflets of the middle canopy leaves had the highest number of different stages of the mite and bottom pair of leaflets (R2/L2) of top canopy leaves had the lowest number of eggs, nymphs and adults.

The mean number of eggs per leaflet, on leaves of bottom, middle and top canopy was 55.38, 77.59 and 37.14, respectively and the variance was 84.84, 85.90 and 84.91 respectively (Table 5). The mean number of nymphs per leaflet on leaves of bottom, middle and top canopy were 32.38, 54.58 and 26.24, respectively and the variance was 78.69, 88.14 and 62.46, respectively. The mean number of adults on leaflets of leaves of bottom, middle and top canopy was 17.05, 24.15 and 9.48, respectively and the variance was 24.82, 39.51 and 16.86, respectively.

Coefficient of variance for the population of different stages of *T. urticae* on different leaflets was computed. The number of different stages on each leaflet was correlated with the total number of respective stages present on the plant. Number of eggs on leaflets of the top canopy leaves had high variance and low correlation value and aggregated in I^{st} quadrant and those on leaflets of bottom canopy leaves had low variance and low correlation value and aggregated in III^{rd} quadrant (Fig. 4), whereas number of eggs on leaflets of the middle canopy leaves had low variance but high correlation value and aggregated in IV^{th} quadrant. The nymphs and adults followed similar type of distribution as eggs (Figs. 5 and 6).

Table. 2. Distribution of eggs of *Tetranychus urticae* on leaflets of rose at different canopy levels

	Bottom canopy					Middle canopy					Top canopy				
	T	L1	R1	L2	R2	T	L1	R1	L2	R2	T	L1	R1	L2	R2
Mean	66.76	59.94	50.14	54.65	45.42	86.08	79.82	73.95	77.48	70.62	44.02	39.77	34.68	36.19	31.06
SD.	9.81	9.85	8.83	8.88	8.58	9.78	9.11	9.49	7.98	9.84	9.86	9.53	8.50	9.83	8.20
Variance	96.28	97.07	78.13	79.02	73.70	95.65	83.08	90.23	63.70	96.89	97.25	90.97	72.33	96.75	67.27

T = Terminal leaflet.
L1/R1 = Middle leaflets.
L2/R2 = Bottom leaflets.

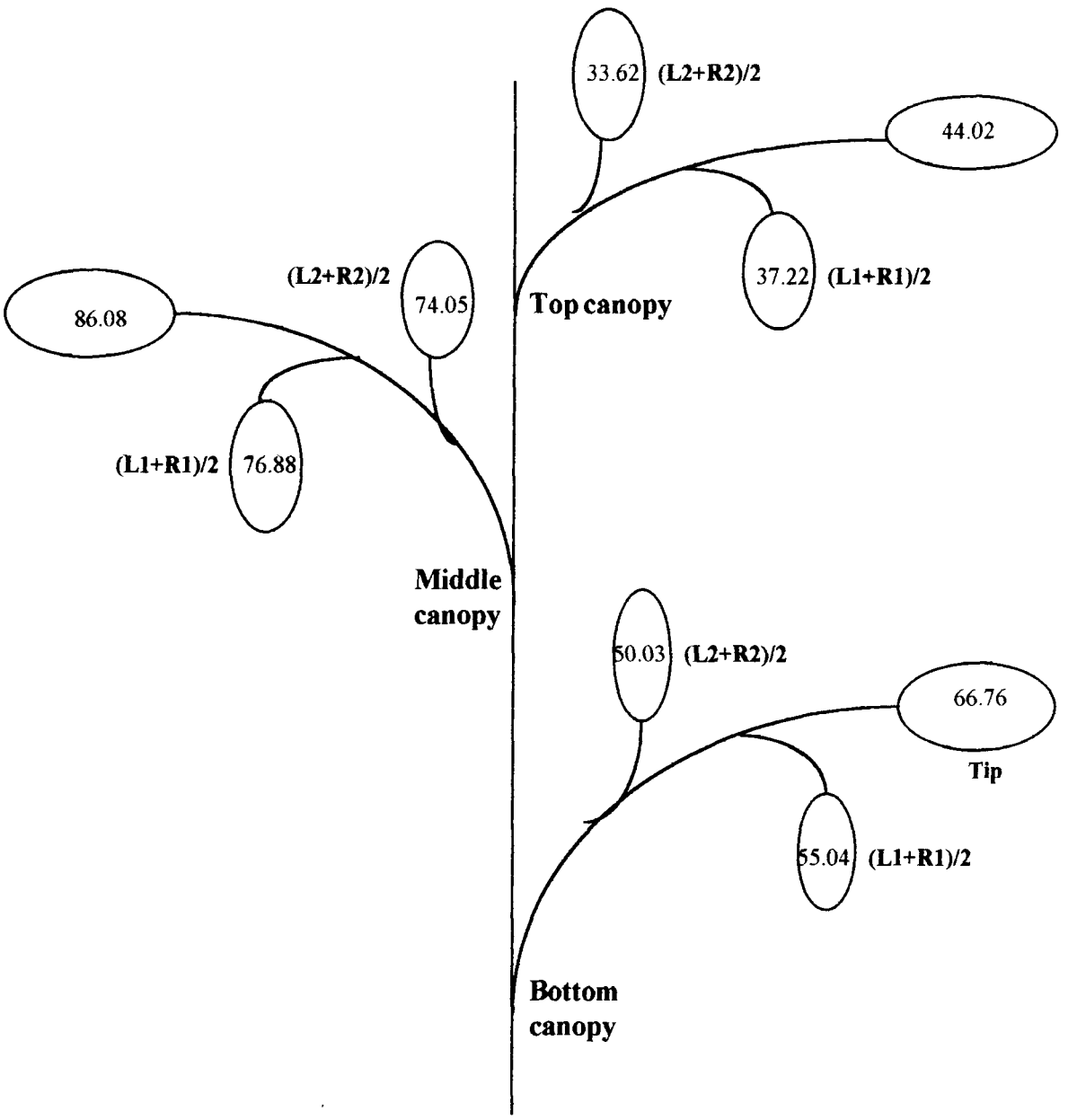

Fig. 1. Mean number of eggs of *T. urticae* on leaflets of rose plant at different canopy levels

Table. 3. Distribution of nymphs of *Tetranychus urticae* on leaflets of rose at different canopy levels

	Bottom canopy					Middle canopy					Top canopy				
	T	L1	R1	L2	R2	T	L1	R1	L2	R2	T	L1	R1	L2	R2
Mean	42.09	35.83	28.54	32.21	23.24	66.52	54.61	52.49	54.67	44.65	33.04	26.34	24.70	25.44	21.70
SD.	8.78	9.33	8.39	9.90	7.75	8.16	9.68	9.8	9.90	9.27	7.99	8.03	8.88	7.86	6.57
Variance	77.21	87.56	70.54	98.09	60.07	66.6	93.83	96.04	98.07	86.11	63.85	64.48	78.91	61.79	43.27

T = Terminal leaflet.
L1/R1 = Middle leaflets.
L2/R2 = Bottom leaflets.

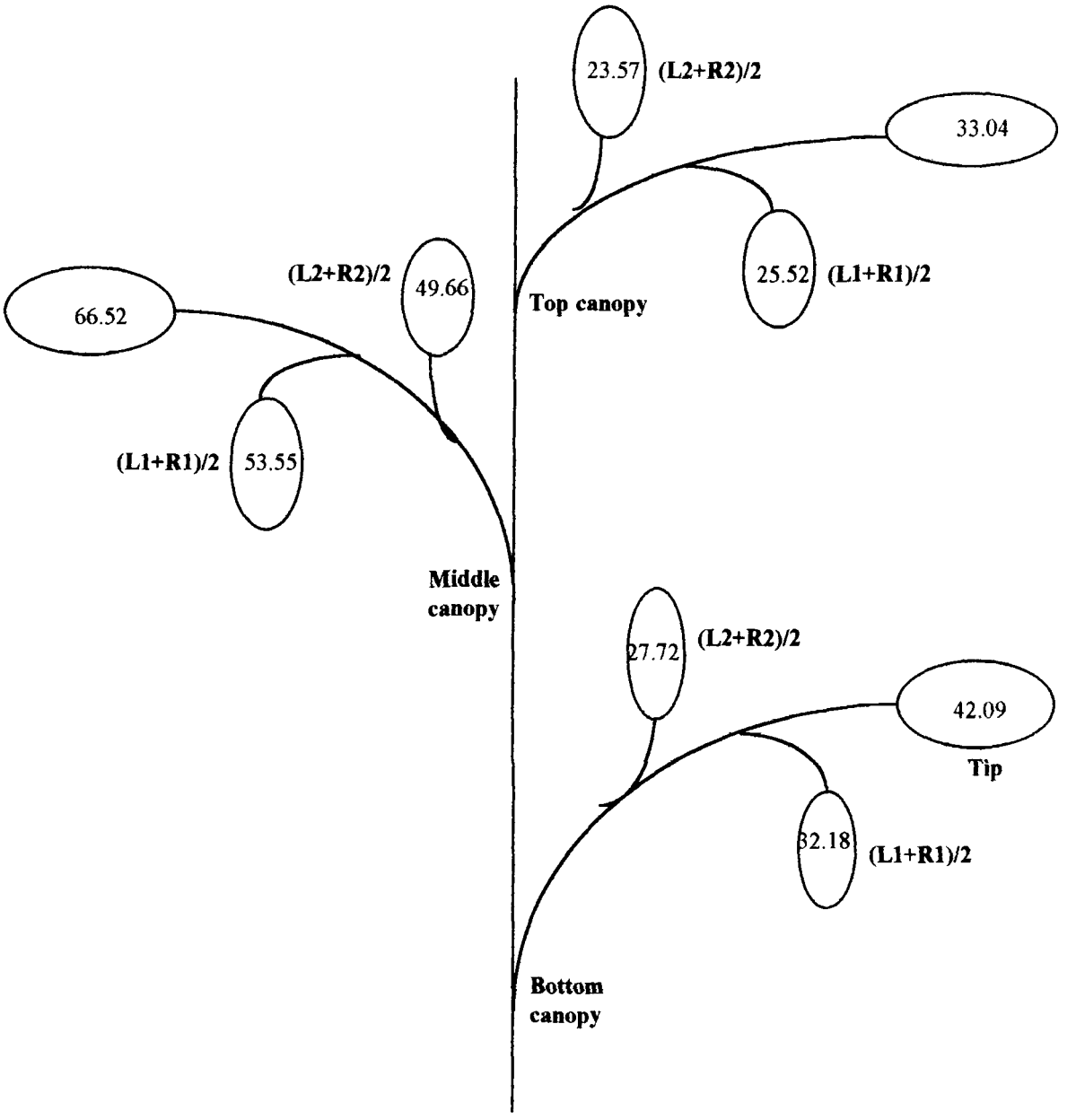

Fig. 2. Mean number of nymphs of *T. urticae* on leaflets of rose plant at different canopy levels

Table. 4. Distribution of adults of *Tetranychus urticae* on leaflets of rose at different canopy levels.

	Bottom canopy					Middle canopy					Top canopy				
	T	L1	R1	L2	R2	T	L1	R1	L2	R2	T	L1	R1	L2	R2
Mean	19.97	17.97	16.18	16.55	14.58	30.96	26.86	20.78	22.94	19.24	13.56	11.08	8.08	8.41	6.28
SD.	5.99	4.40	3.91	5.06	5.26	6.17	6.43	6.52	6.68	5.54	4.88	3.69	4.41	3.92	3.46
Variance	35.97	19.44	15.35	25.65	27.69	38.09	41.42	42.58	44.70	30.80	23.82	13.63	19.45	15.39	12.03

T = Terminal leaflet.
L1/R1 = Middle leaflets.
L2/R2 = Bottom leaflets.

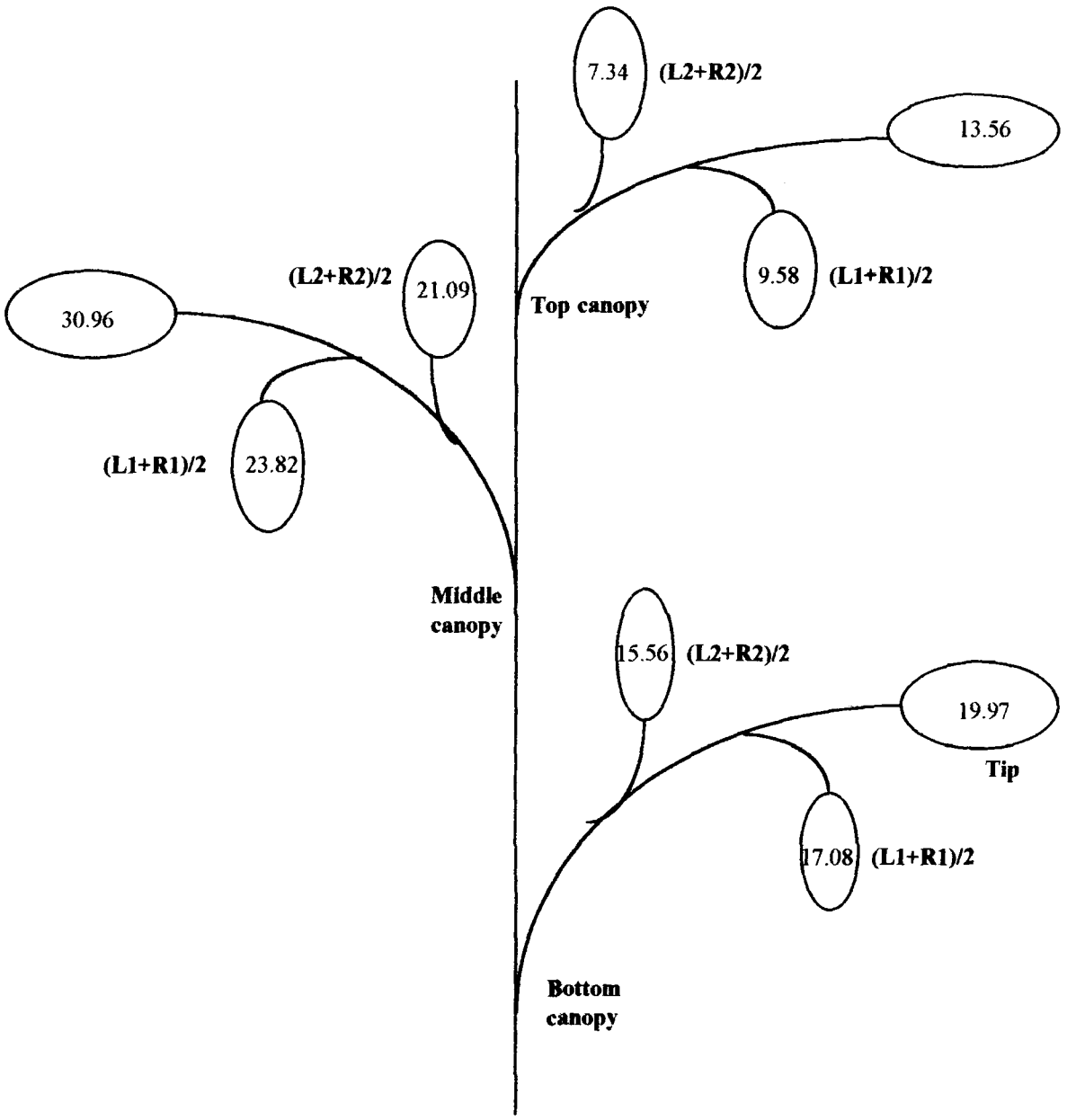

Fig. 3. Mean number of adults of *T. urticae* on leaflets of rose plant at different canopy levels

Table. 5. Distribution of eggs, nymphs and adults (total) of *Tetranychus urticae* on leaflets of rose at different canopy levels

	Bottom	Middle	Top
Eggs			
Total	276.91	387.95	185.70
Mean number/leaflet	55.38	77.59	37.14
SD.	9.19	9.24	9.18
Variance	84.84	85.90	84.91
Nymphs			
Total	161.9	272.9	131.2
Mean number/leaflet	32.38	54.58	26.24
SD.	8.83	9.36	7.86
Variance	78.69	88.14	62.46
Adults			
Total	85.25	120.75	47.40
Mean number/leaflet	17.05	24.15	9.48
SD.	4.92	6.26	4.07
Variance	24.82	39.51	16.86

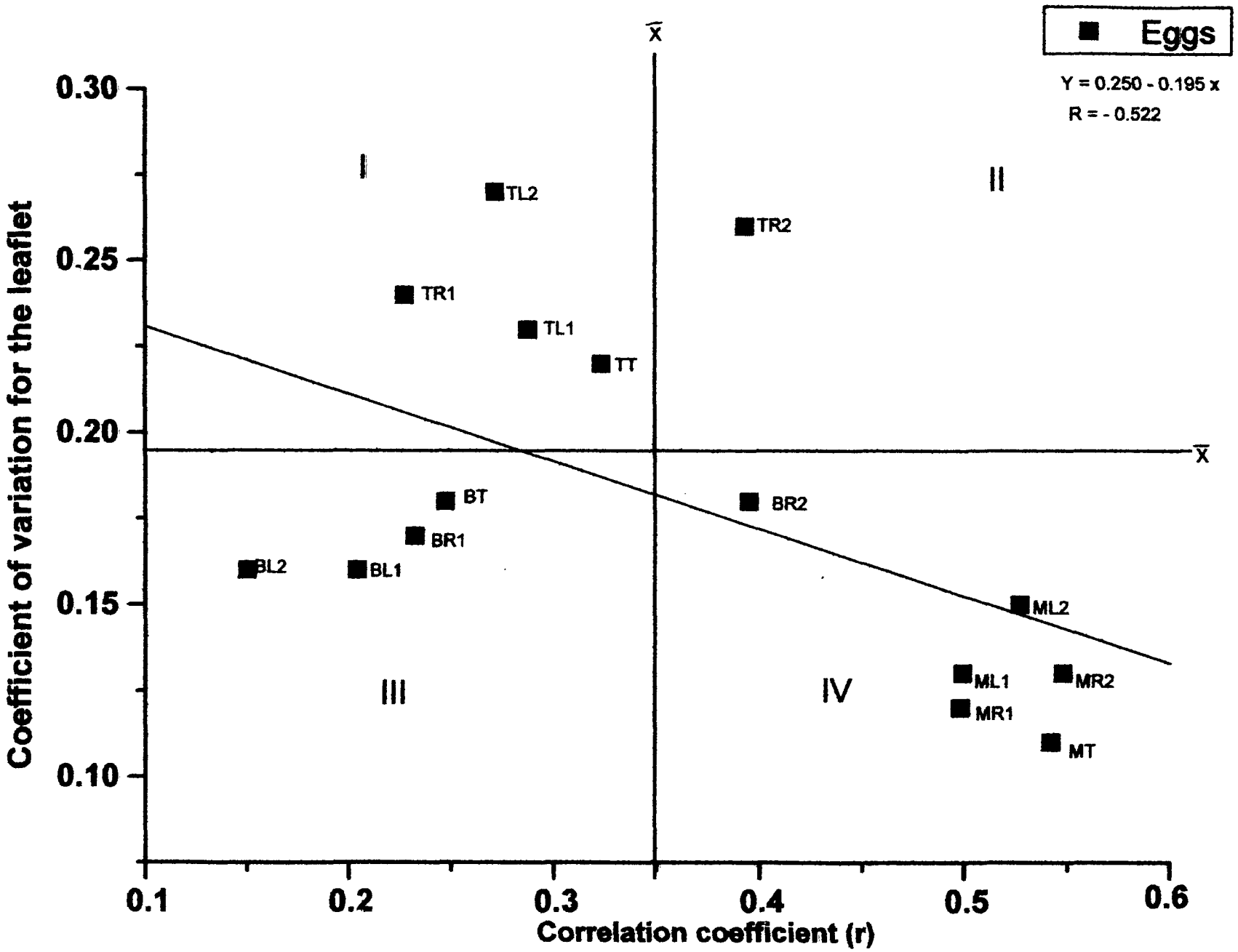

Fig. 4 : Relationship between CV of the number of eggs on individual leaflet and correlation between this number and the population mean

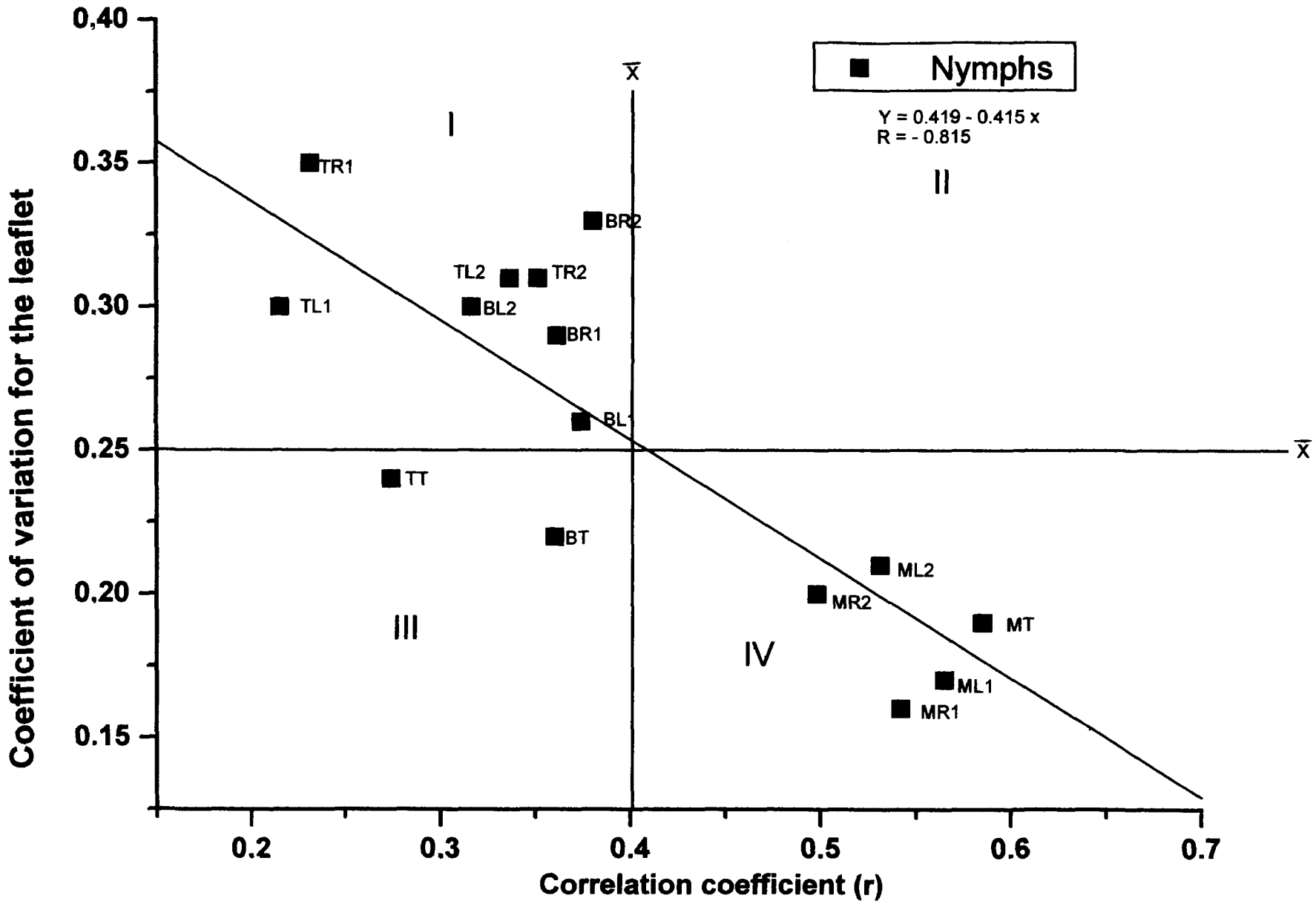

Fig. 5 : Relationship between CV of the number of nymphs on individual leaflet and correlation between this number and the population mean

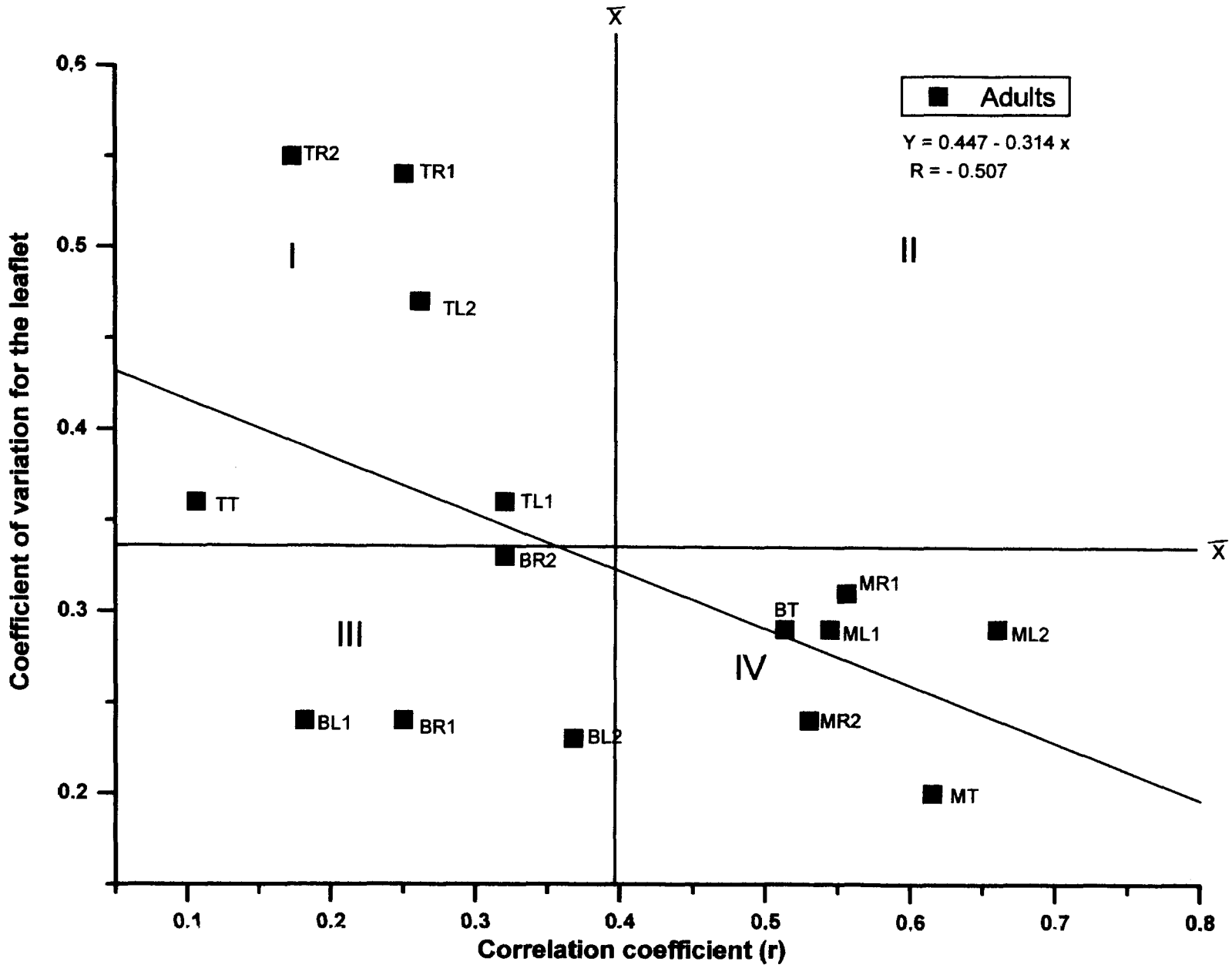

Fig. 6 : Relationship between CV of the number of adults on individual leaflet and correlation between this number and the population mean

4.2 Functional and numerical responses of *Amblyseius longispinosus* :

The functional and numerical responses of *A. longispinosus* to different densities of eggs (10, 20, 30, 40, 50, 60, 70 and 80 per 5 X 5 cm area) of *T. urticae* was studied in the laboratory at 26.4° C and 70 per cent RH. As the prey density increased, initially the consumption rate also increased, but attained a plateau for densities higher than 60 eggs, when it fed on 41 eggs (Table 6, Fig. 7).

The functional response was explained by the linear regression equation Y = 9.514 + 0.476 X, (R = 0.929). Similarly the numerical response also showed an increasing response for lower densities of prey eggs, but reached a plateau at a prey density 60 eggs. (Table 6, Fig. 7). This could be explained by the linear regression equation Y = 1.358 + 0.16 X, (R = 0.91).

4.3 Dispersal of *Amblyseius longispinosus* :

4.3.1 Population of *Tetranychus urticae* and *Amblyseius longispinosus* one week after release of the predators

0 metre : At the time of release of the predators 235.5 eggs, 130.4 nymphs and 50.12 adults per leaflet were recorded. One week after release of predators the population reduced to 150.2 eggs, 100.3 nymphs and 45.2 adults per leaflet, respectively, whereas the number of eggs, nymphs and adults of the predator recorded was 2.8, 3.8 and 1.6, respectively (Table 7, Fig. 9-12).

1 metre : One week after release of the predators at the center of the bed, no predators were recorded 1 metre from the point of release. The number of eggs, nymphs and adults of the prey was 240.5, 150.3 and 70.4 per leaflet, respectively at the time of release of the predators. One week later these had increased to 248.3, 155.35 and 76.05, respectively (Table 7, Fig. 9-12).

One week after the release of the predators, they were not recovered, either at one metre from the point of release or beyond, hence the prey population at all these sampling points increased, as at one metre distance mentioned above.

Table 6. Functional and numerical responses of *Amblyseius longispinosus* to varying prey densities (eggs of *Tetranychus urticae)*

	Number of *Tetranychus urticae* eggs per leaf **							
	10	20	30	40	50	60	70	80
Number of prey eggs consumed by one female *	8.00 ± 0.71	17.8 ± 0.83	26.60 ± 0.84	32.60 ± 0.55	39.20 ± 0.84	41.00 ± 0.71	41.2 ± 0.83	41.4 ± 0.54
Number of eggs laid * (eggs / female)	1.40 ± 0.54	2.20 ± 0.45	3.20 ± 0.44	4.80 ± 0.44	5.20 ± 0.83	5.60 ± 0.89	5.40 ± 0.89	5.40 ± 0.89

* Mean of five replications. Duration of observation - 24 hrs.

** leaf size - 5 x 5 cm.

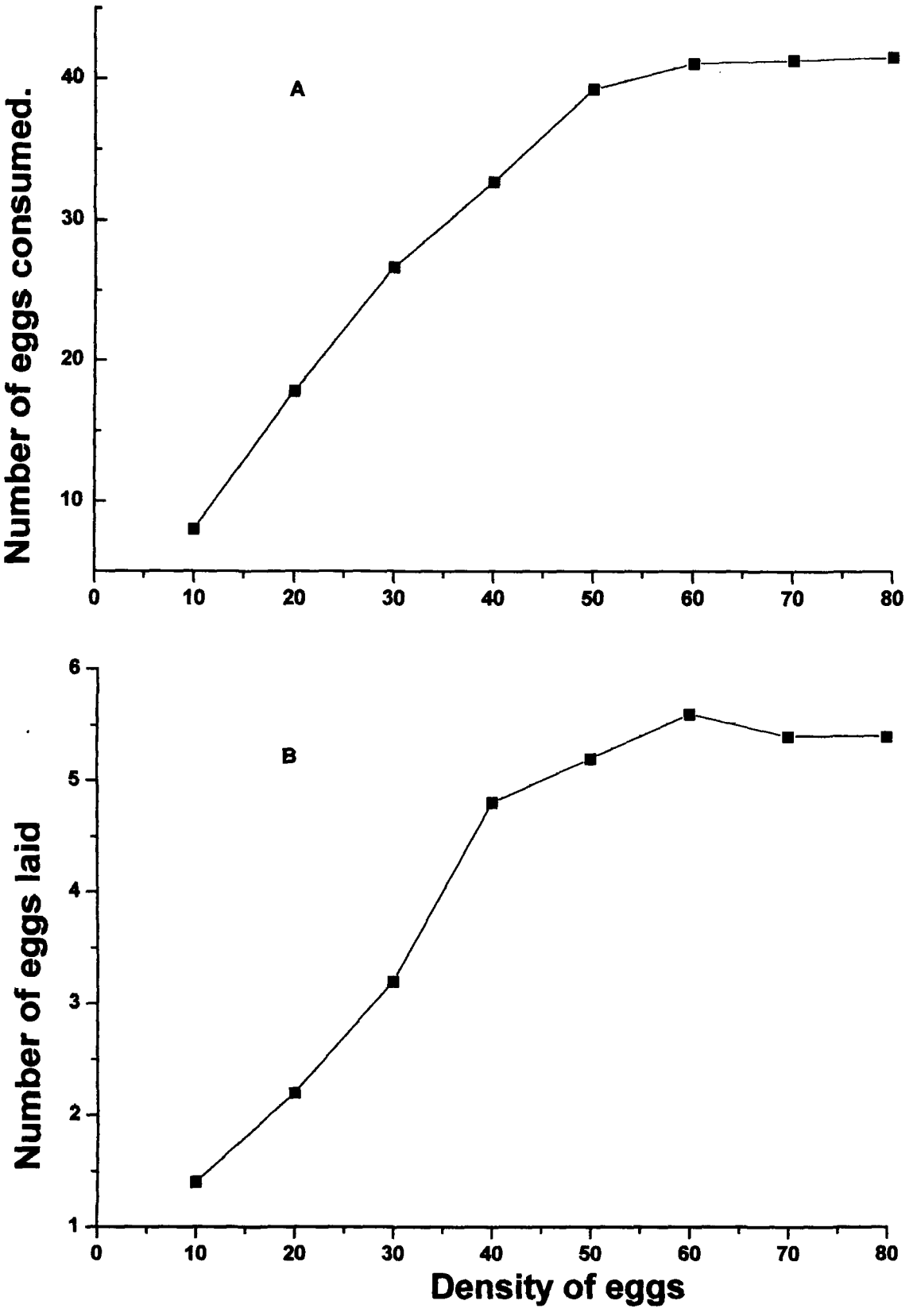

Fig. 7: Functional response (A) and numerical response(B) of *Amblyseius longispinosus* (adult female) to eggs of *T. urticae*.

The mean dispersal index for eggs, nymphs and adults of predator was zero at all these points, meaning during the first week there was no dispersal of predators (Table 7, Fig. 8).

4.3.2 Population of *Tetranychus urticae* and *Amblyseius longispinosus* two weeks after release of the predators

0 metre : The number of eggs, nymphs and adults of the predator was 8.5, 5.5 and 3.6 per leaflet, respectively, whereas that of the prey was reduced to 58.3, 45.25 and 10.35 per leaflet, respectively (Table 7, Fig. 9-12).

1 metre : During the second week, predators were observed one metre from the point of release. The number of eggs, nymphs and adults of the predators recorded was 4.4, 5.45 and 3.45 per leaflet, respectively, while 209.05 eggs, 116.7 nymphs and 59.15 adults per leaflet of the prey was recorded (Table 7, Fig. 9-12).

3 metres : Three metres from the point of release, the predators were not recovered during the second week. The number of eggs, nymphs and adult stages of the prey recorded at this point was 236.9, 132.9 and 73.55 per leaflet, respectively (Table 7, Fig. 9-12).

Similarly 6 metres and 10 metres beyond the point of release increase in the prey population was observed two weeks after release of the predators. The mean dispersal index for eggs, nymphs and adults of the predators was 0.34, 0.50 and 0.49 per leaflet, respectively (Table 7, Fig. 8).

4.3.3 Population of *Tetranychus urticae* and *Amblyseius longispinosus* three weeks after release of the predators

0 metre : The number of eggs, nymphs and adult stages of the predator decreased to 4.8, 3.8 and 0.0 per leaflet, respectively, similarly that of the prey had also reduced to 9.85, 5.30 and 3.20 per leaflet, respectively (Table 7, Fig. 9-12).

1 metre : The number of eggs, nymphs and adults of the predator was 11.2, 7.8 and 4.2 per leaflet, respectively, whereas the prey population comprised of 175.15 eggs, 83.75 nymphs and 38.20 adults per leaflet (Table 7, Fig.9-12).

3 metres : At this distance the predators were recorded three weeks after release. Egg, nymph and adult population of the predator was 2.1, 4.4 and 4.15 per leaflet, respectively. The number of eggs, nymphs and adults of the prey reduced to 201.1, 111.5 and 58.2 per leaflet respectively (Table 7, Fig. 9-12).

6 metres : Three weeks after release the predators were not recovered at six metres from the point of release. The egg, nymph and adult population of the prey had increased to 239.5, 144.7 and 70.55 per leaflet respectively (Table 7, Fig. 9-12).

10 metres : Since the predator was not recorded beyond three metres, the prey population at this point also increased to 241.1 eggs, 139.75 nymphs and 63.9 adults per leaflet (Table 7, Fig. 9-12).

The mean dispersal index for eggs, nymphs and adults of the predator was 0.97, 1.31 and 2.01 per leaflet, respectively (Table 7, Fig. 8).

4.3.4 Population of *Tetranychus urticae* and *Amblyseius longispinosus* four weeks after release of the predators

0 metre : The egg, nymph and adult stages of the predator and prey reduced to 0.6, 1.2, 0.0 and 2.5, 1.3, 0.2 leaflet, respectively (Table 7, Fig. 9-12).

1 metre : The egg, nymph and adult population of the predator was 16.65, 8.5 and 4.55 per leaflet, respectively, and that of the prey was 157.70, 42.35 and 25.80 per leaflet, respectively (Table 7, Fig. 9-12).

3 metres : The number of eggs, nymphs and adult stages of the predator was 18.65, 13.80 and 5.95 per leaflet, respectively and that of the prey was 171.65, 85.50 and 40.35 per leaflet, respectively (Table 7, Fig. 9-12).

6 metres : After four weeks the predator was recorded at six metre distance, 5.50 eggs, 6.00 nymphs and 3.85 adults were observed per leaflet. The population of eggs, nymphs and

adults of the prey was 201.75, 110.95 and 53.25 per leaflet, respectively (Table 7, Fig. 9-12).

10 metres : The predator had still not moved this distance and the number of eggs, nymphs and adults of the prey was 249.4, 152.45 and 73.3 per leaflet, respectively (Table 7, Fig. 9-12).

The mean dispersal index of the predator for fourth week was 2.55, 2.91 and 4.16 for eggs, nymphs and adults per leaflet, respectively (Table 7, Fig. 8).

4.3.5 Population of *Tetranychus urticae* and *Amblyseius longispinosus* five weeks after release of the predators

0 metre : The number of eggs, nymphs and adult stages of the prey and predator were reduced to zero (Table 7, Fig. 9-12).

1 metre : The number of eggs, nymphs and adult stages of the predator and prey was 14.15, 10.6, 4.25 and 26.75, 10.05 and 10.00 per leaflet, respectively (Table 7, Fig. 9-12).

3 metres : The number of eggs, nymphs and adult stages of the predator was 26.80, 17.25 and 6.40 per leaflet, respectively, whereas the prey population was 124.05, 56.55 and 25.50 per leaflet, respectively (Table 7, Fig. 9-12).

6 metres : The total number of all stages of the predator was 38.80 per leaflet whereas the prey population was 281.8 per leaflet (Table 7, Fig. 9-12).

10 metres : At this distance the predator was recorded five weeks after release. Egg, nymph and adult population of the predator was 4.5, 5.75 and 2.25 per leaflet, respectively. The number of eggs, nymphs and adult stages of the prey reduced to 213.15, 127.5 and 60.5 per leaflet, respectively (Table 7, Fig. 9-12).

The mean dispersal index for eggs, nymphs and adults of the predator was 4.02, 1.92 and 4.33 per leaflet, respectively (Table 7, Fig. 8).

4.3.6 Population of *Tetranychus urticae* and *Amblyseius longispinosus* six weeks after release of the predators

0 metre : Neither the predator nor the prey was recorded.

1 metre : The number of eggs, nymphs and adult stages of the predator reduced to 6.80, 3.45 and 2.00 per leaflet, the prey population had also reduced to 8.75, 1.60 and 2.30 per leaflet, respectively (Table 7, Fig. 9-12).

3 metres : The number of eggs, nymphs and adult stages of both predator and prey reduced to 18.30, 12.80, 9.40 and 95.55, 11.65, 13.45 per leaflet, respectively (Table 7, Fig. 9-12).

6 metres : Total population of all stages of the predator and prey reduced to 34.5 and 168.45 per leaflet, respectively (Table 7, Fig. 9-12).

10 metres : The number of eggs, nymphs and adult stages of the predator increased to 22.65, 12.75 and 6.65 per leaflet, respectively, whereas the prey population reduced to 172.75 eggs, 80.35 nymphs and 48.05 adults per leaflet (Table 7, Fig. 9-12).

The mean dispersal index for eggs, nymphs and adults of the predator was 4.92, 5.88 and 5.52 per leaflet, respectively (Table 7, Fig. 8).

4.3.7 Population of *Tetranychus urticae* and *Amblyseius longispinosus* seven weeks after release of the predators

0 metre : Neither the prey nor the predator was recorded.

1 metre : The number of eggs, nymphs and adults of the predator and prey was reduced to 1.75, 1.55, 1.40 and 2.70, 0.20, 0.40 per leaflet, respectively (Table 7, Fig. 9-12).

3 metres : The total population of all stages of the predator and prey reduced to 11.10 and 26.65 per leaflet, respectively (Table 7, Fig. 9-12).

6 metres : The predator and prey population reduced to 18.68 and 56.20 per leaflet, respectively (Table 7, Fig. 9-12).

10 metres : The number of eggs, nymphs and adult stages of the predator and prey reduced to 13.85, 7.90, 3.90 and 58.25, 20.20, 14.15 per leaflet, respectively (Table 7, Fig. 9-12).

The mean dispersal index for eggs, nymphs and adults of the predator was 6.93, 6.83 and 6.17 per leaflet, respectively (Table 7, Fig. 8).

4.3.8 Population of *Tetranyhus urticae* and *Amblyseius longispinosus* eight weeks after release of the predators

0 metre : Neither the predator nor the prey was recorded.

1 metre : The number of eggs, nymphs and adult stages of the predator reduced to 0.25, 0.00 and 0.35 per leaflet, respectively, whereas the prey population reduced to zero (Table 7, Fig. 9-12).

3 metres : The number of eggs, nymphs and adults of the predator reduced to 0.55, 0.80 and 0.40 per leaflet, respectively, similarly that of the prey had also reduced to 0.75, 0.20 and 0.24 per leaflet, respectively (Table 7, Fig. 9-12).

6 metres : Total population of all stages of the predator and the prey reduced to 2.25 and 2.45 per leaflet, respectively (Table 7, Fig. 9-12).

10 metres : The number of eggs, nymphs and adult stages of the predator and the prey reduced to 1.00, 1.50, 1.15 and 2.30, 2.50, 1.30 per leaflet, respectively (Table 7, Fig. 9-12).

The mean dispersal index for eggs, nymphs and adults of the predator was 7.56, 6.57 and 7.21 per leaflet, respectively (Table 7, Fig. 8).

4.4. Management of Spider mites

4.4.1 Management of *Tetranychus urticae* using *Amblyseius longispinosus* at different predator - prey ratios :

4.4.1.1 Predator - prey ratio of 1 : 40

Before release of the predators the number of eggs of *T. urticae* was 213.48 per leaflet. This reduced to 2.60 eggs per leaflet, twelve days after release of the predator

Table. 7. Number of different stages of prey and the predator per leaflet recorded, at different distances from the point of release, subsequent to release of predators and dispersal index of the predator

Week(s)	Stages	0 metre		1 metre		3 metres		6 metres		10 metres		MDI. of
		Predator	Prey	Predator	Prey	Predator	Prey	Predator	Prey	Predator	Prey	Predator
1	E	2.80	150.20	0.0	248.30	0.0	212.90	0.0	200.00	0.0	172.55	0.0
	N	3.80	100.30	0.0	155.35	0.0	10.8.05	0.0	104.75	0.0	75.90	0.0
	A	1.60	45.20	0.0	76.05	0.0	48.05	0.0	63.40	0.0	42.75	0.0
	T	8.20	295.70	0.0	479.70	0.0	369.00	0.0	368.15	0.0	291.20	0.0
2	E	8.50	58.30	4.40	209.05	0.0	236.90	0.0	223.40	0.0	228.20	0.34
	N	5.50	45.25	5.45	116.70	0.0	132.90	0.0	125.90	0.0	109.30	0.50
	A	3.60	10.35	3.45	59.15	0.0	73.55	0.0	73.55	0.0	55.40	0.49
	T	17.60	113.90	13.30	384.90	0.0	443.35	0.0	422.85	0.0	393.20	0.43
3	E	4.80	9.85	11.25	175.15	2.10	201.10	0.0	239.50	0.0	241.10	0.97
	N	3.80	5.30	7.80	83.75	4.40	111.50	0.0	144.70	0.0	139.75	1.31
	A	0.00	3.20	4.20	38.20	4.15	58.20	0.0	70.55	0.0	63.90	2.01
	T	8.60	18.35	23.25	297.10	10.65	370.80	0.0	454.75	0.0	444.75	1.30
4	E	0.60	2.50	16.65	157.70	18.65	171.65	5.50	201.75	0.0	249.40	2.55
	N	1.20	1.30	8.50	42.35	13.80	85.50	6.00	110.95	0.0	152.45	2.91
	A	0.0	0.20	4.55	25.80	5.95	40.35	3.85	53.25	0.0	73.30	4.16
	T	1.80	4.0	29.70	225.85	38.40	297.50	15.35	365.95	0.0	475.15	2.78
5	E	0.0	0.0	14.15	26.75	26.80	124.05	21.85	168.45	4.50	213.15	4.02
	N	0.0	0.0	10.60	10.05	17.25	56.55	11.00	79.35	5.75	127.50	1.92
	A	0.0	0.0	4.25	10.00	6.40	25.50	5.95	34.00	2.25	60.50	4.33
	T	0.0	0.0	29.00	46.80	50.45	206.10	38.80	281.80	12.50	401.50	4.12
6	E	0.0	0.0	6.80	8.75	18.30	95.55	17.25	116.00	22.65	172.75	4.92
	N	0.0	0.0	3.45	1.60	12.80	11.65	11.10	33.20	12.75	80.35	5.88
	A	0.0	0.0	2.00	2.30	9.40	13.45	6.15	19.25	6.65	48.05	5.52
	T	0.0	0.0	12.25	12.65	40.50	120.65	34.50	168.45	42.05	301.15	5.89
7	E	0.0	0.0	1.75	2.70	5.80	22.25	10.15	39.55	13.85	58.25	6.93
	N	0.0	0.0	1.55	0.20	3.05	1.35	5.20	9.10	7.90	20.20	6.83
	A	0.0	0.0	1.40	0.40	2.25	3.00	3.30	7.55	3.90	14.15	6.17
	T	0.0	0.0	4.70	3.30	11.10	26.65	18.68	56.20	22.65	92.60	6.76
8	E	0.0	0.0	0.25	0.0	0.55	0.75	0.60	1.35	1.00	2.30	6.46
	N	0.0	0.0	0.0	0.0	0.80	0.20	0.65	1.25	1.50	2.50	7.56
	A	0.0	0.0	0.35	0.0	0.40	0.24	1.00	0.85	1.15	1.30	6.57
	T	0.0	0.0	0.60	0.0	1.75	1.19	2.25	3.45	3.65	6.10	7.21

E = eggs; N = nymphs; A = adults; T = E + N + A; MDI = Mean Dispersal Index.

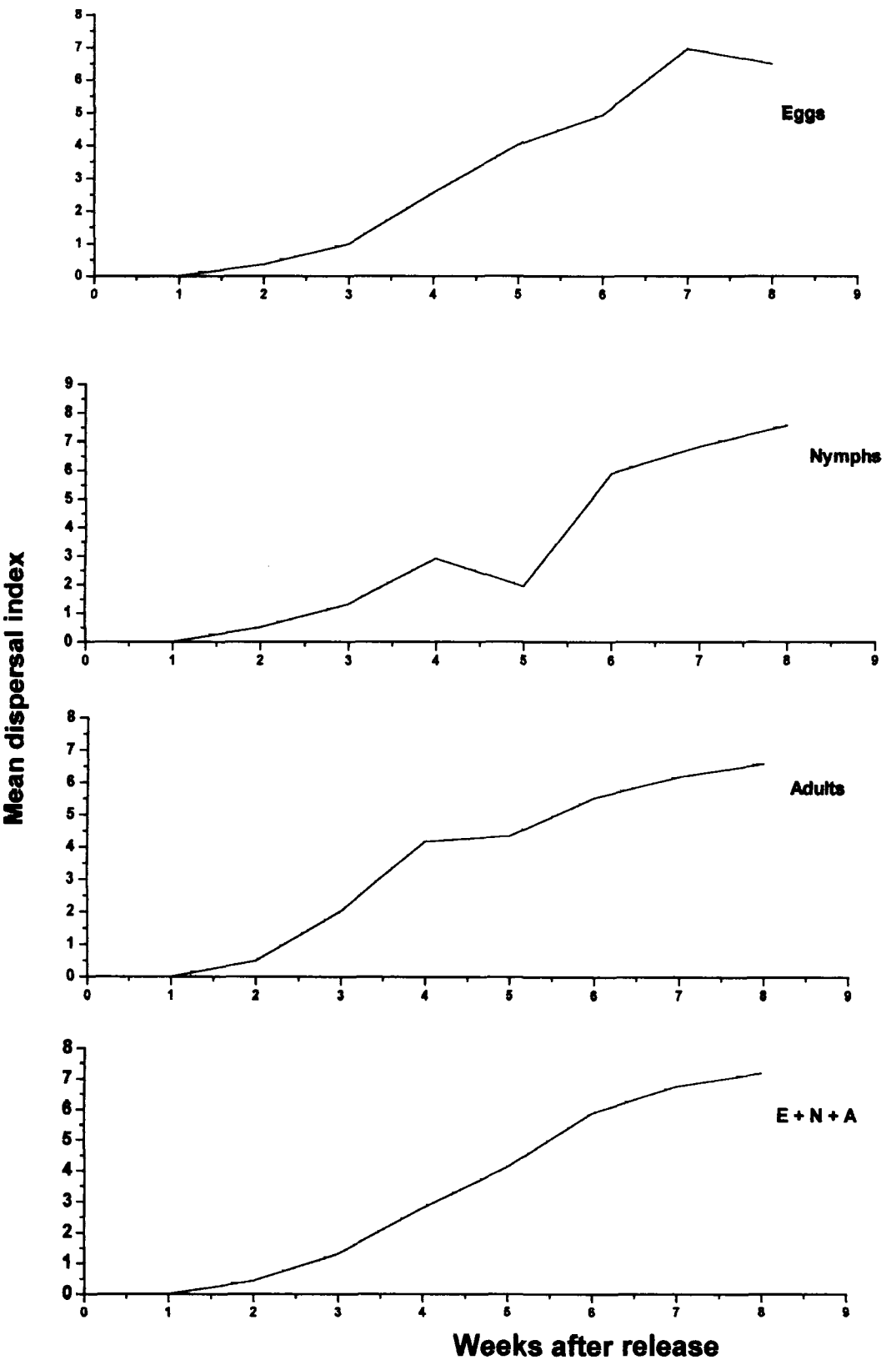

Fig. 8: Mean dispersal index for different life stages of *A. longispinosus*

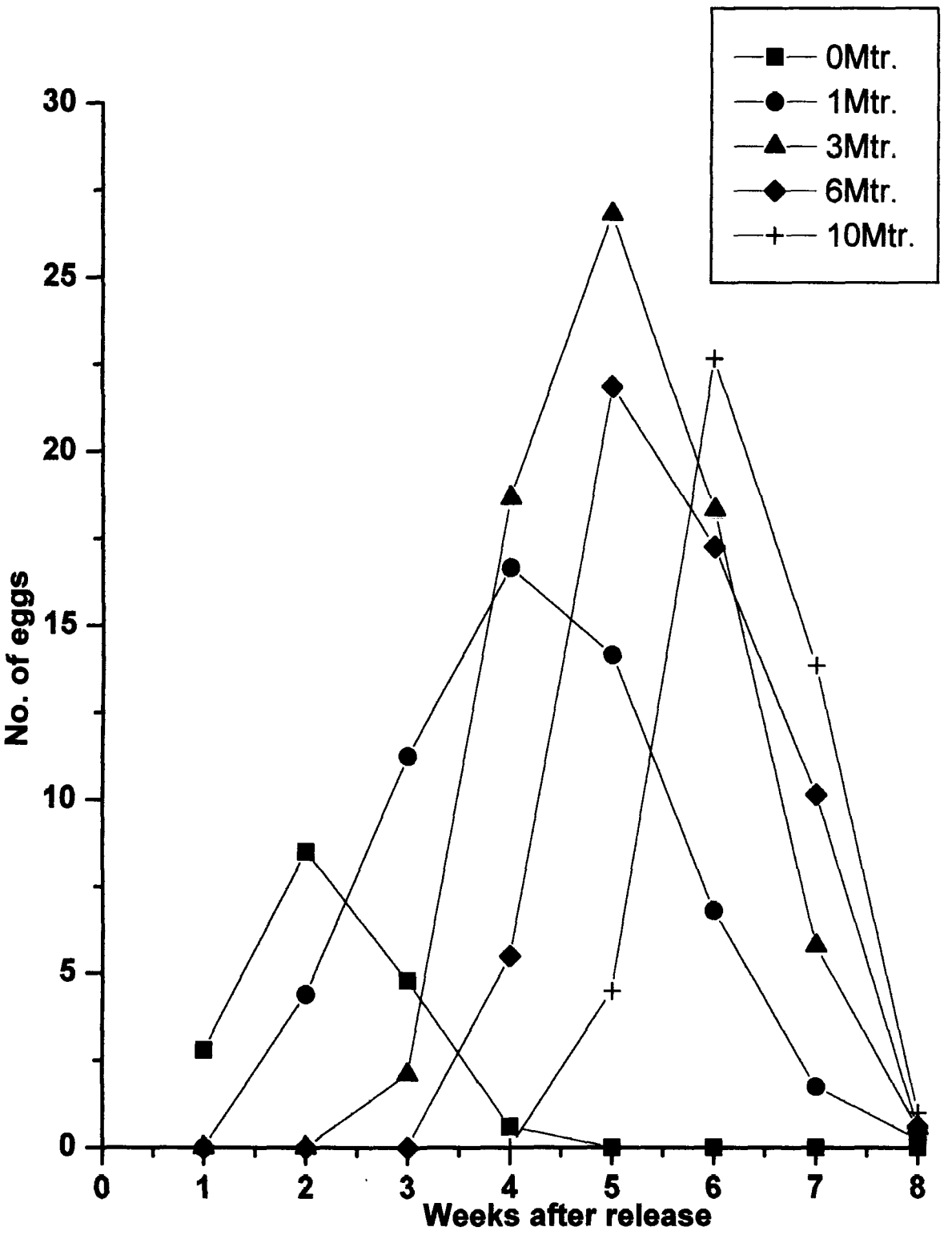

Fig. 9: Population of eggs of *A. longispinosus* recorded at different distances from the point of release on different sampling dates

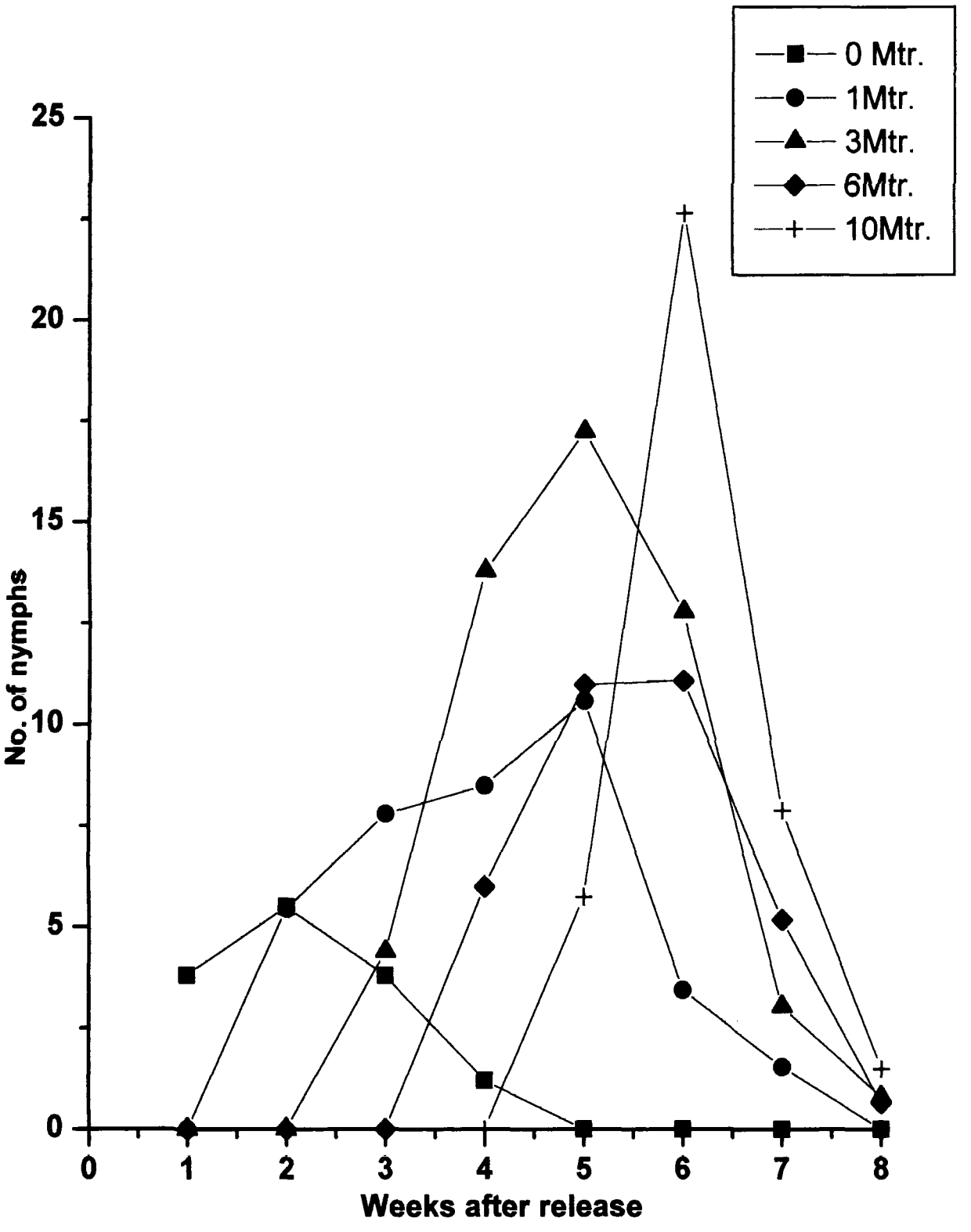

Fig. 10: Population of nymphs of *A. longispinosus* recorded at different distances from the point of release, on different sampling dates

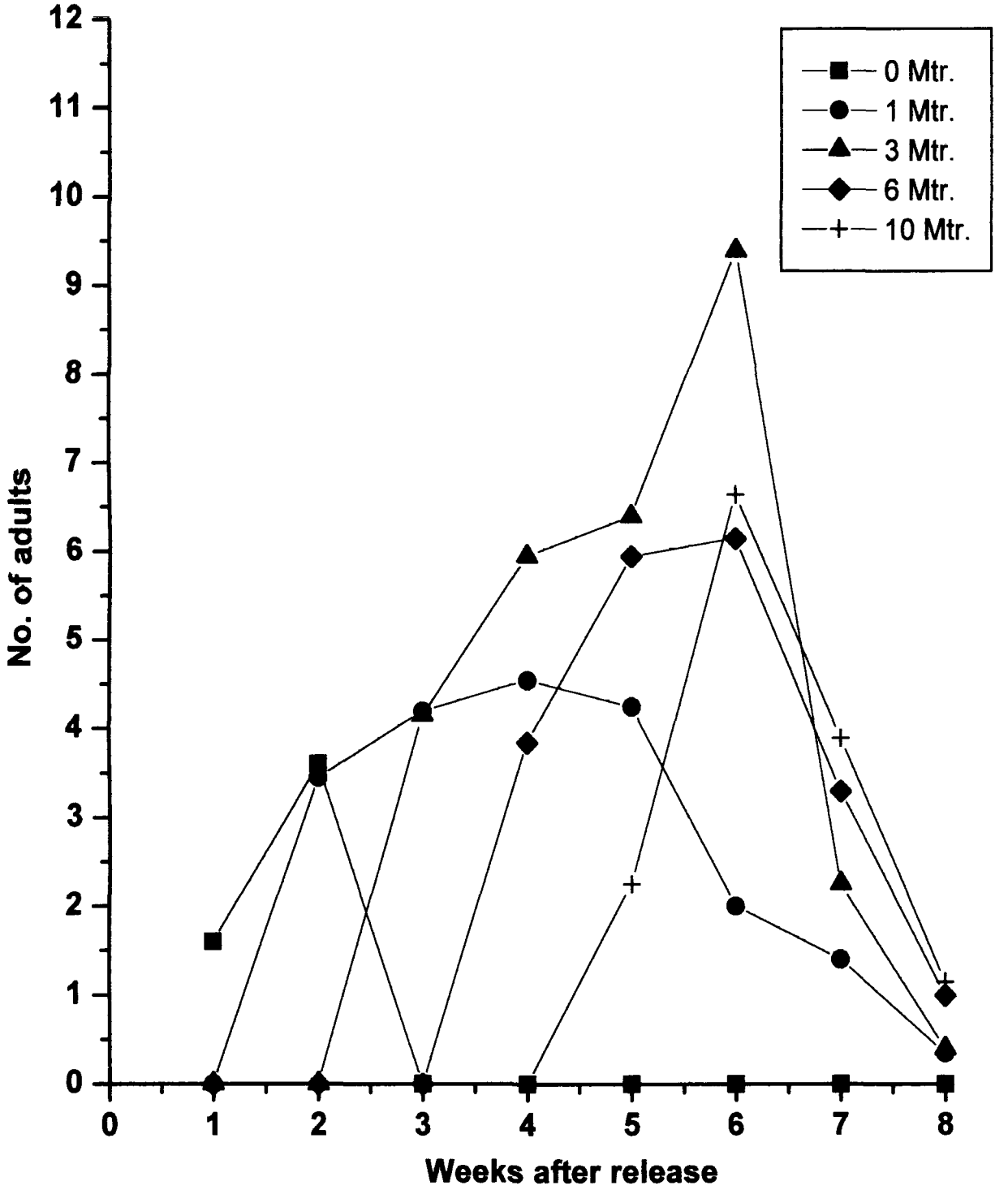

Fig. 11: Population of adults of *A. longispinosus* recorded at different distances from the point of release, on different sampling dates

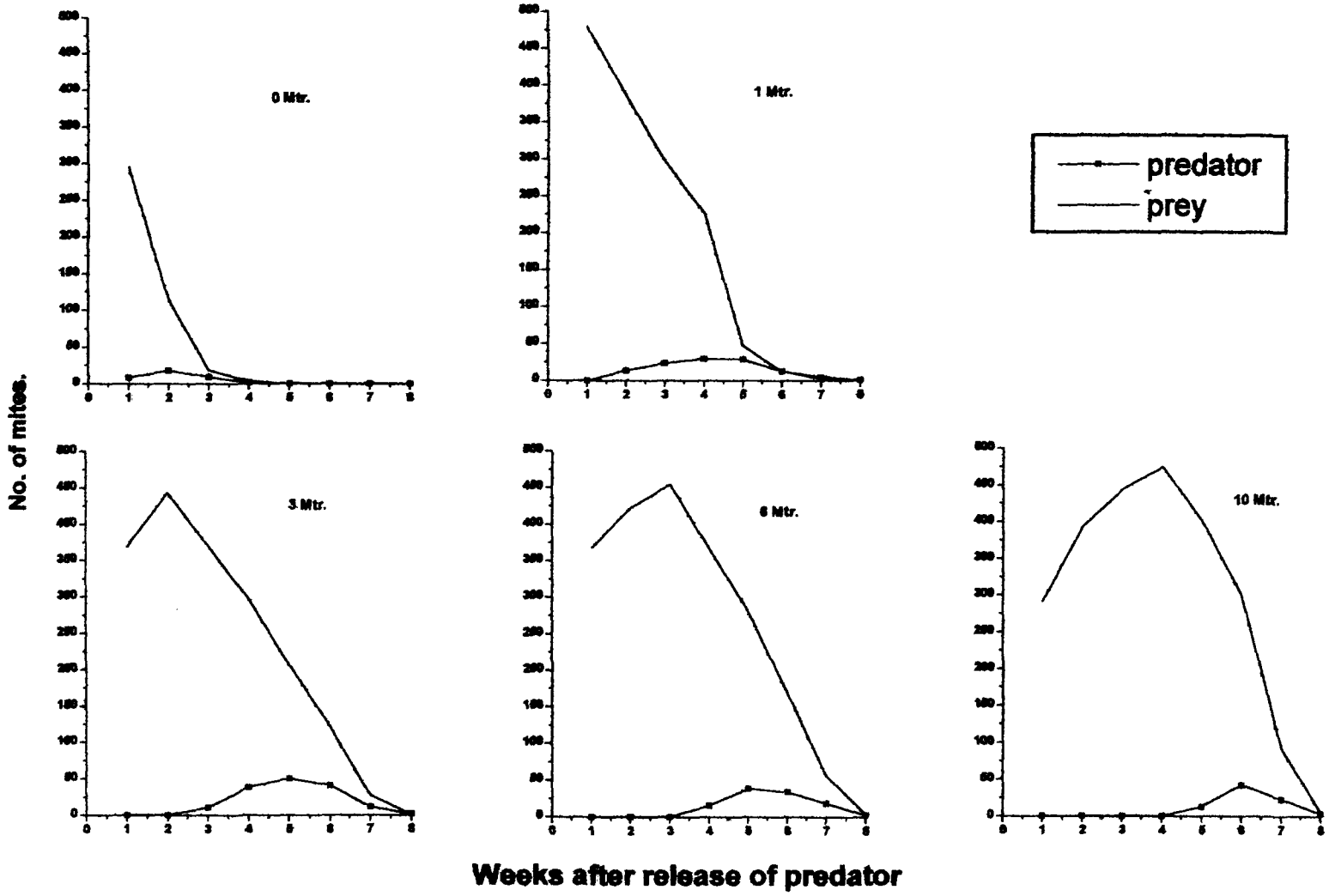

Fig. 12: Total population (eggs+ nymphs+ adults) of prey and predator at different distances, on different sampling dates

(Table 8, Fig. 13). The population of nymphs which was 37.75 per leaflet was reduced to 0.63 per leaflet sixteen days after release of the predator (Table 9, Fig. 13). The population of adults of the spider mite before release of the predator was 16.66 per leaflet, till four days after release this increased slightly, but later started declining and sixteen days after release of the predator this was reduced to 0.2 per leaflet (Table 10, Fig. 13). Reduction in total population of all stages of *T. urticae* was observed sixteen days after release of the predator (Table 11).

4.4.1.2 Predator - prey ratio of 1 : 80

In this ratio, twenty days after release of the predator, the number of eggs was reduced to 3.87 per leaflet (Table 8, Fig. 13) and that of nymphs to 1.91 per leaflet (Table 9, Fig. 13), but in case of adults the population increased upto four days after release then afterwards this was decreased, to reach 1.08 per leaflet twentyfour days after release (Table 10, Fig. 14). Reduction in number of all stages of *T. urticae* was observed twenty four days after release (Table 11).

4.4.1.3 Predator - prey ratio of 1 : 160

The number of eggs started declining from the time of release of the predators, 3.79 eggs per leaflet was recorded twenty four days after release (Table 8, Fig. 14). The number of nymphs reduced to 1.96 per leaflet twenty four days after release (Table 9, Fig. 14). But the number of adults increased during the first four days after release of the predators and then declined. The number of adults reached 0.07 per leaflet or leaflet twenty eight days after release (Table 10, Fig. 14). Reduction in number of all stages of *T. urticae* was observed twenty eight days after release of the predator (Table 11).

4.4.1.4 Predator - prey ratio of 1 : 200

At the time of release of the predators the number of eggs was 203.18 per leaflet, this reduced to 1.55 per leaflet twenty eight days after release of the predators (Table 8, Fig. 14). But in nymphs the population increased initially upto four days after release and then declined to zero thirty two days after release of the predator (Table 9, Fig. 14). Similar trend was observed in the population of adults which increased initially upto four

days after release to reach 0.51 adults per leaflet twenty eight days after release (Table 10, Fig. 14). Reduction in total population of all stages of *T. urticae* was observed twenty eight days after release of the predator (Table 11).

4.4.1.5 Predator - prey ratio of 1 : 400

At the time of release of the predators the number of eggs was 206.67 per leaflet, this reduced gradually from the day of release of the predators to 3.84 per leaflet thirty two days after release (Table 8, Fig. 15). But the population of nymphs increased initially upto four days after release and then gradually declined to 2.37 per leaflet thirty two days after release of the predator (Table 9, Fig. 16). Similar trend was observed in the population of adults, which increased initially upto four days after release then decreased gradually to reach 1.18 per leaflet thirty two days after release, (Table 10, Fig. 16). Reduction in the total population of all stages of the *T. urticae* was observed thirty two days after release of the predator (Table 11).

4.4.1.6 Predator - prey ratio of 1 : 600

The population of eggs showed similar decreasing trend (Table 8, Fig. 15). The nymphal population increased initially up to four days after release and then gradually declined to 3.77 per leaflet thirty two days after release of the predator (Table 9, Fig. 15). Similar trend was observed in the population of the adults, which increased initially upto four days after release then gradually decreased to reach 1.89 per leaflet thirty two days after release (Table 10, Fig. 15). Reduction in the total population of all stages of *T. urticae* was observed thirty two days after release of the predators (Table 11).

4.4.1.7 Predator - prey ratio of 1 : 800

The number of eggs started declining from the time of release of the predators, 59.91 eggs per leaflet was recorded thirty two days after release of predators (Table 8, Fig. 16). The number of nymph increased initially upto four days after release of the predators then gradually decreased to 17.65 nymphs per leaflet thirty two days after release of the predator (Table 9, Fig. 16). Similar trend was observed in the population of the adults, which increased initially upto four days after release to reach 6.87 adults per

leaflet thirty two days after release (Table 10, Fig. 16). Reduction in the total population of all stages of *T. urticae* was observed thirty two days after release of the predator (Table 11).

4.4.1.8 Predator - prey ratio of 1 : 1000

The egg population followed decreasing trend and reached 74.19 per leaflet thirty two days after release (Table 8, Fig. 16). The nymph and adult population of *T. urticae* increased initially upto four days after release of the predator then gradually decreased to 34.40 and 13.29 per leaflet, respectively, thirty two days after release of the predators (Table 9-10, Fig. 16).

4.4.1.9 Predator - ratio of 1 : 1200

At the time of release of the predators the number of eggs was 197.32 per leaflet, this reduced to 85.82 per leaflet thirty two days after release of the predators (Table 8, Fig. 17). But the population of nymphs and adults increased initially upto four days after release of the predators then gradually decreased to 36.21 and 11.93 per leaflet, respectively thirty two days after release of the predators (Table 9-10, Fig. 17).

4.4.1.10 Predator free control

In predator free plots the number of eggs of *T. urticae* increased and reached peak population of 182.5 per leaflet eight days after start of the study. Then the population started to decline upto thirty two days (Table 8, Fig. 17). The nymphal and adult populations reached the peaks twenty days after initiation of the study and later their population decreased (Table 9-10, Fig. 17). Total population of all stages of *T. urticae* increased upto sixteen days and then gradually declined (Fig. 18). Reduction in population of *T. urticae* on predator free plants was mainly due to unsuitability of leaves of rose and also due to predation, to a little extent, by the phytoseiids which had moved in from plots on either side where the predators were released.

Table. 8: Number of *Tetranychus urticae* eggs per leaflet of rose plants on which *Amblyseius longispinosus* were released at different ratios

Treatments (a:b)	Pre release	Days after release							
		4	8	12	16	20	24	28	32
1:40	213.48 (14.62)	118.19 (10.87)	38.93 (6.27)	2.60 (1.75)	0 (0.707)	0 (0.707)	0 (0.707)	0 (0.707)	0 (0.707)
1:80	214.18 (14.65)	137.31 (11.73)	53.77 (7.36)	18.17 (4.31)	15.73 (4.02)	3.87 (2.08)	0 (0.707)	0 (0.707)	0 (0.707)
1:160	206.00 (14.37)	142.54 (11.91)	57.72 (7.62)	28.10 (5.34)	21.05 (4.63)	17.91 (4.28)	3.67 (2.02)	0 (0.707)	0 (0.707)
1:200	203.18 (14.27)	150.13 (12.27)	118.27 (10.89)	31.43 (5.64)	31.34 (5.64)	27.12 (5.25)	15.17 (3.95)	1.55 (1.42)	0 (0.707)
1:400	206.67 (14.39)	163.5 (12.8)	125.45 (11.22)	63.11 (7.97)	37.11 (6.13)	37.15 (6.13)	24.34 (4.98)	11.92 (3.52)	3.84 (2.07)
1:600	219.39 (14.82)	169.5 (12.03)	153.16 (12.39)	85.09 (9.24)	83.26 (9.15)	83.14 (9.14)	31.08 (5.61)	20.94 (4.62)	9.54 (3.16)
1:800	204.96 (14.33)	174.5 (13.21)	163.72 (12.81)	127.21 (11.30)	112.65 (10.63)	110.55 (10.53)	107.66 (10.39)	101.62 (10.10)	59.91 (7.77)
1:1000	211.64 (14.56)	179.34 (13.41)	164.44 (12.84)	130.36 (11.43)	122.01 (11.06)	121.61 (11.05)	120.04 (10.97)	106.67 (10.35)	74.19 (8.64)
1:1200	197.32 (14.06)	184.64 (13.6)	177.07 (13.22)	133.80 (11.58)	126.94 (11.28)	126.79 (11.28)	124.33 (11.17)	120.12 (10.98)	85.82 (9.29)
Control	171.69 (13.12)	179.5 (13.41)	182.5 (13.52)	165.54 (12.88)	156.34 (12.52)	151.22 (12.31)	149.97 (12.26)	136.53 (11.7)	119.71 (10.96)

At 32 DAR: F - Test * ; CD. at P= 0.05 - (0.181). Values in the parentheses are $\sqrt{(x + 0.5)}$ values
Control - Without predator. a : b = Predator : Prey. DAR = Days After Release

Table. 9: Number of *Tetranychus urticae* nymphs on leaflets of rose plants on which *Amblyseius longispinosus* were released at different ratios

Treatments (a:b)	Pre release	Days after release							
		4	8	12	16	20	24	28	32
1:40	37.75 (6.185)	25.87 (5.32)	14.58 (3.88)	0.67 (1.08)	0.63 (1.06)	0 (0.707)	0 (0.707)	0 (0.707)	0 (0.707)
1:80	37.19 (6.13)	35.71 (6.017)	17.77 (4.27)	9.13 (3.09)	5.37 (2.42)	1.91 (1.53)	0 (0.707)	0 (0.707)	0 (0.707)
1:160	39.32 (6.3)	36.06 (6.04)	22.34 (4.77)	13.21 (3.70)	7.28 (2.74)	5.92 (2.51)	1.96 (1.56)	0 (0.707)	0 (0.707)
1:200	43.6 (6.64)	52.79 (7.29)	25.74 (5.12)	19.01 (4.42)	16.00 (4.05)	13.99 (3.80)	6.31 (2.59)	1.22 (1.31)	0 (0.707)
1:400	44.08 (6.67)	56.47 (7.54)	28.97 (5.42)	21.61 (4.70)	18.93 (4.40)	17.81 (4.27)	10.91 (3.37)	4.51 (2.22)	2.37 (1.69)
1:600	39.38 (6.31)	59.98 (7.77)	32.92 (5.78)	24.24 (4.97)	23.41 (4.88)	22.81 (4.82)	14.98 (3.93)	10.92 (3.38)	3.77 (2.05)
1:800	41.3 (6.46)	63.19 (7.98)	36.41 (6.07)	26.67 (5.21)	23.22 (4.87)	23.32 (4.88)	22.11 (4.75)	20.93 (4.63)	17.65 (4.25)
1:1000	36.94 (6.11)	67.75 (8.26)	52.41 ()7.27	51.17 (7.19)	47.97 (6.96)	45.38 (6.77)	42.32 (6.54)	38.83 (6.27)	34.40 (5.91)
1:1200	39.47 (6.32)	63.64 (8.01)	55.46 (7.46)	60.24 (7.79)	58.23 (7.66)	51.95 (7.24)	48.25 (6.98)	43.23 (6.61)	36.21 (6.06)
Control	40.69 (6.418)	56.6 (7.55)	58.6 (7.69)	60.98 (7.84)	63.38 (7.99)	67.92 (8.27)	59.34 (7.73)	50.47 (7.14)	41.50 (6.48)

At 32 DAR : F - Test * ; CD. at P = 0.05 - (0.25). Values in the parentheses are $\sqrt{(x + 0.5)}$ values
Control - Without predator. a : b = Predator : Prey. DAR = Days After Release

Table. 10: Number of *Tetranychus urticae* adults on leaflets of rose plants on which *Amblyseius longispinosus* were released at different ratios

Treatments (a:b)	Pre release	Days after release							
		4	8	12	16	20	24	28	32
1:40	16.66 (4.14)	18.11 (4.31)	4.16 (22.15)	0.24 (0.86)	0.2 (0.84)	0 (0.707)	0 (0.707)	0 (0.707)	0 (0.707)
1:80	13.66 (3.75)	21.73 (4.71)	5.54 (2.45)	1.96 (1.56)	1.76 (1.5)	0.97 (1.19)	1.08 (1.256)	0 (0.707)	0 (0.707)
1:160	16.51 (4.12)	23.74 (4.92)	7.54 (2.83)	2.66 (1.77)	3.25 (1.93)	1.06 (1.22)	2.81 (1.81)	0.07 (0.75)	0 (0.707)
1:200	15.5 (3.99)	26.30 (5.17)	7.76 (2.86)	3.48 (1.99)	4.67 (2.27)	3.62 (2.01)	4.29 (2.18)	0.51 (1.00)	0 (0.707)
1:400	15.71 (4.02)	29.52 (5.47)	9.36 (3.14)	8.87 (3.05)	6.49 (2.64)	4.57 (2.25)	6.78 (2.69)	1.51 (1.42)	1.18 (1.29)
1:600	14.97 (3.93)	32.82 (5.77)	12.33 (3.58)	8.79 (3.04)	8.92 (3.06)	5.73 (2.49)	8.83 (3.05)	3.58 (2.01)	1.89 (1.54)
1:800	16.04 (4.06)	35.63 (6.01)	14.86 (3.92)	10.78 (3.35)	8.73 (3.03)	8.54 (3.00)	11.24 (3.43)	7.33 (2.79)	6.87 (2.71)
1:1000	14.08 (3.82)	38.18 (6.21)	24.02 (4.95)	21.35 (4.67)	20.32 (4.56)	19.97 (4.52)	18.85 (4.39)	16.64 (4.13)	13.29 (3.7)
1:1200	15.80 (4.04)	42.75 (6.57)	23.91 (4.91)	24.19 (4.97)	22.01 (4.74)	19.02 (4.42)	18.49 (4.35)	14.49 (3.87)	11.93 (3.52)
Control	14.79 (3.91)	21.92 (4.73)	23.11 (4.85)	23.51 (4.89)	26.47 (5.19)	29.09 (5.44)	23.3 (4.88)	18.89 (4.40)	16.53 (4.12)

At 32 DAR : F - Test * ; CD. at P = 0.05 - (0.24). Values in the parentheses are $\sqrt{(x + 0.5)}$ values,
Control - Without predator. a : b = Predator : Prey. DAR = Days After Release

Table. 11: Total Population of *Tetranychus urticae* per leaflet of rose plants on which *Amblyseius longispinosus* were released at different ratios

Treatments (a:b)	Pre release	Days after release							
		4	8	12	16	20	24	28	32
1:40	267.89 (16.38)	163.68 (12.81)	57.68 (7.62)	3.51 (2.00)	0.83 (1.15)	0 (0.707)	0 (0.707)	0 (0.707)	0 (0.707)
1:80	265.03 (16.29)	194.75 (13.97)	77.08 (8.81)	29.32 (5.46)	22.86 (4.83)	6.75 (2.67)	0.08 (0.76)	0 (0.707)	0 (0.707)
1:160	261.83 (16.19)	195.34 (13.99)	82.59 (9.11)	37.99 (6.20)	28.38 (5.36)	24.86 (5.03)	6.44 (2.63)	0.07 (0.75)	0 (0.707)
1:200	262.28 (16.21)	222.22 (14.92)	147.77 (12.18)	53.92 (7.37)	51.00 (7.17)	44.73 (6.72)	25.03 (5.04)	3.28 (1.94)	0 (0.707)
1:400	266.46 (16.34)	229.37 (15.16)	155.28 (12.48)	88.59 (9.44)	55.52 (7.55)	54.53 (7.42)	39.03 (6.29)	17.89 (4.28)	7.4 (2.81)
1:600	273.76 (16.56)	235.41 (15.36)	188.41 (13.74)	117.12 (10.84)	113.58 (10.68)	111.67 (10.59)	49.96 (7.10)	35.45 (5.99)	15.25 (3.97)
1:800	262.31 (16.21)	248.03 (15.76)	205.97 (14.37)	162.91 (12.78)	144.59 (12.04)	142.34 (11.95)	139.01 (11.81)	129.88 (11.42)	84.47 (9.22)
1:1000	262.67 (16.22)	255.57 (16.00)	240.87 (15.54)	202.89 (14.26)	190.3 (13.81)	186.97 (13.69)	181.26 (13.48)	162.14 (12.75)	121.92 (11.06)
1:1200	252.61 (15.91)	262.61 (16.22)	262.54 (16.22)	218.24 (14.79)	207.18 (14.41)	197.77 (14.08)	197.07 (13.84)	177.85 (13.35)	133.78 (11.58)
Control	227.17 (15.09)	251.61 (15.88)	264.21 (16.27)	250.04 (15.83)	246.22 (15.71)	254.69 (15.97)	232.61 (15.27)	205.89 (14.37)	177.71 (13.35)

At 32 DAR : F - Test * ; CD. at P = 0.05 - (0.23). Values in the parentheses are $\sqrt{(x + 0.5)}$ values,
Control - Without predator. a : b = Predator : Prey. DAR = Days After Release

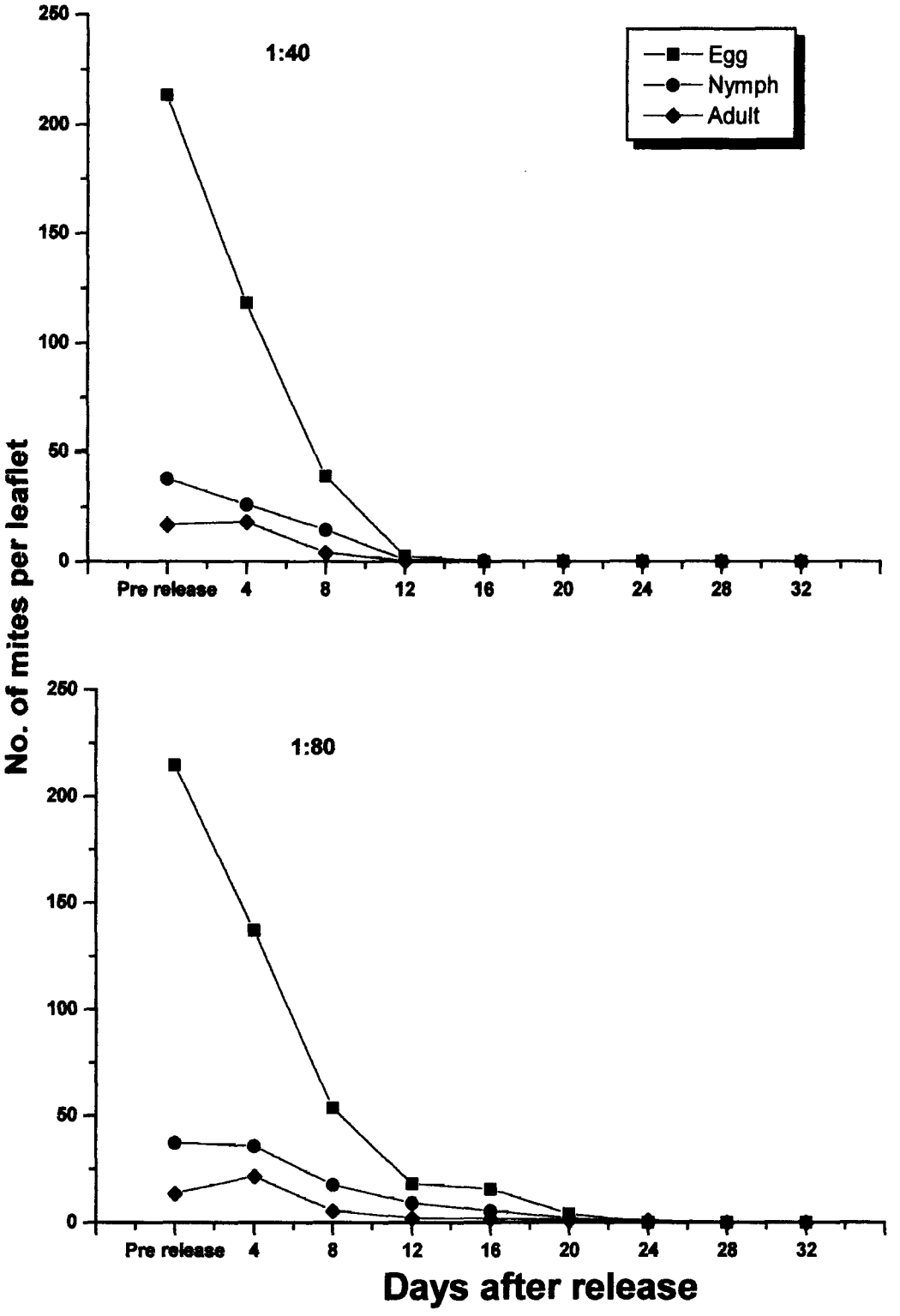

Fig. 13: Population of eggs, nymphs and adults of *T.urticae* on rose plants, where *A.longispinosus* were released at 1 : 40 and 1 : 80 ratios.

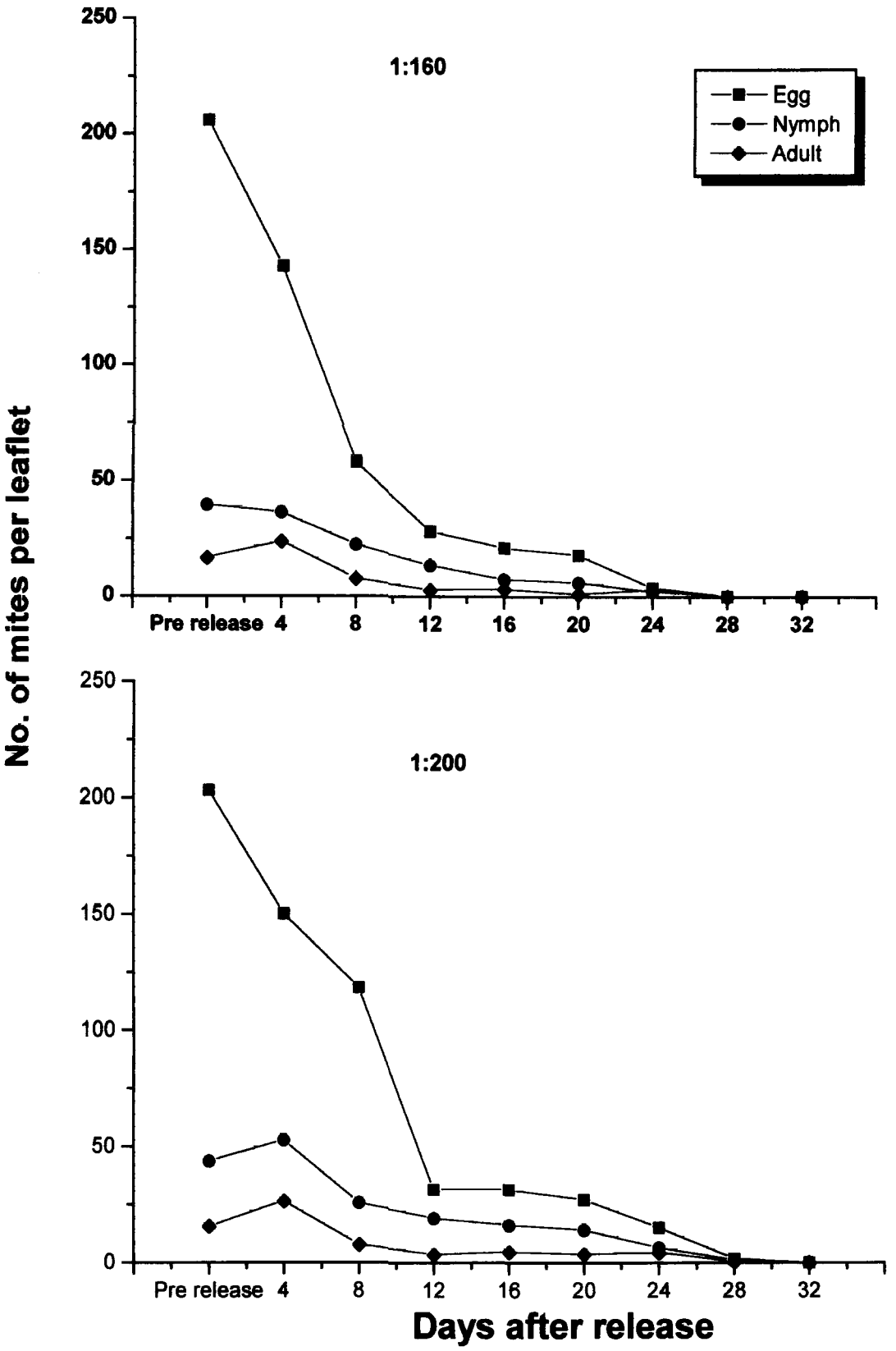

Fig. 14: Population of eggs, nymphs and adults of *T.urticae* on rose plants, where *A.longispinosus* were released at 1 : 160 and 1 : 200 ratios.

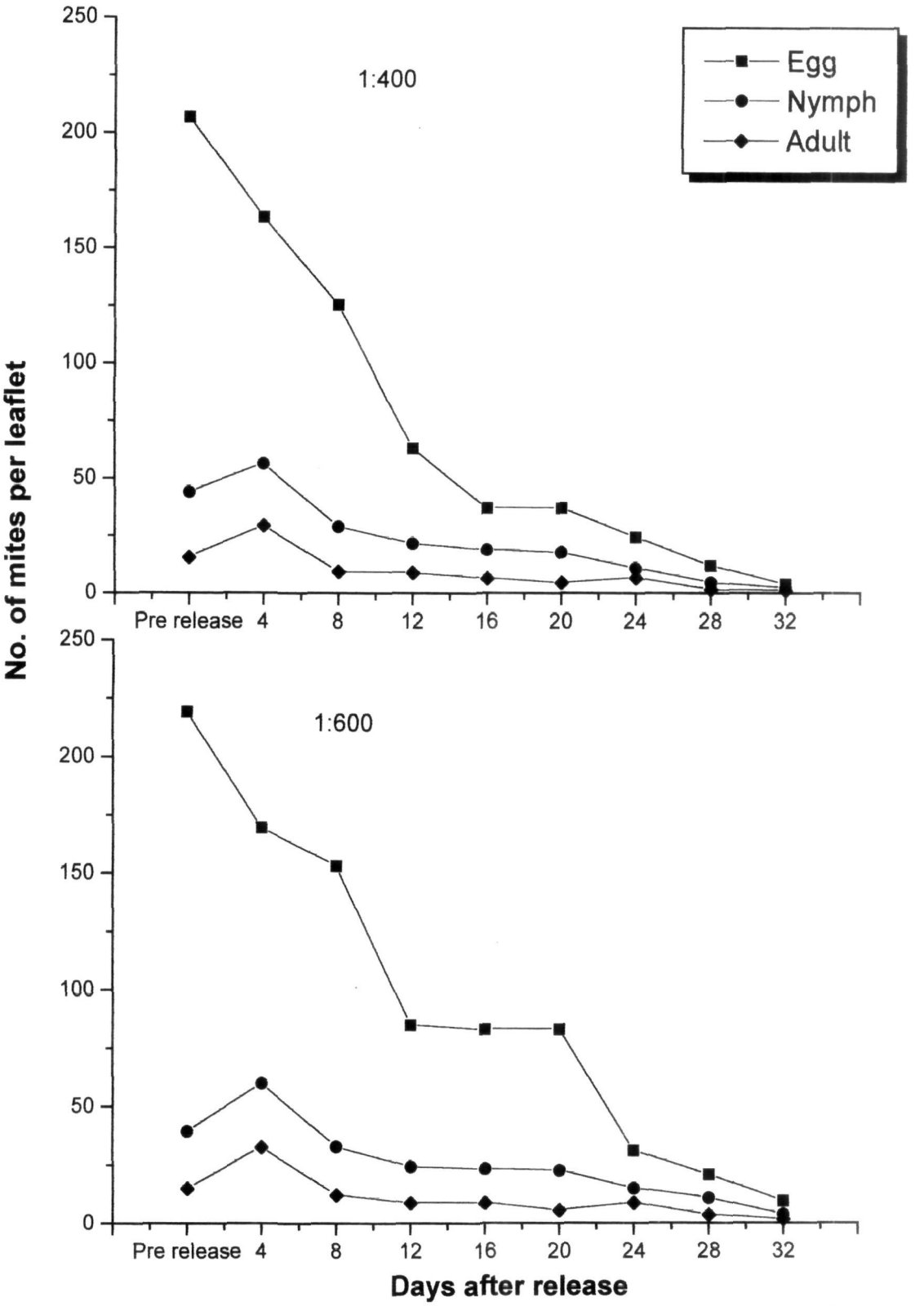

Fig. 15: Population of eggs, nymphs and adults of *T.urticae* on rose plants, where *A.longispinosus* were released at 1 : 400 and 1 : 600 ratios.

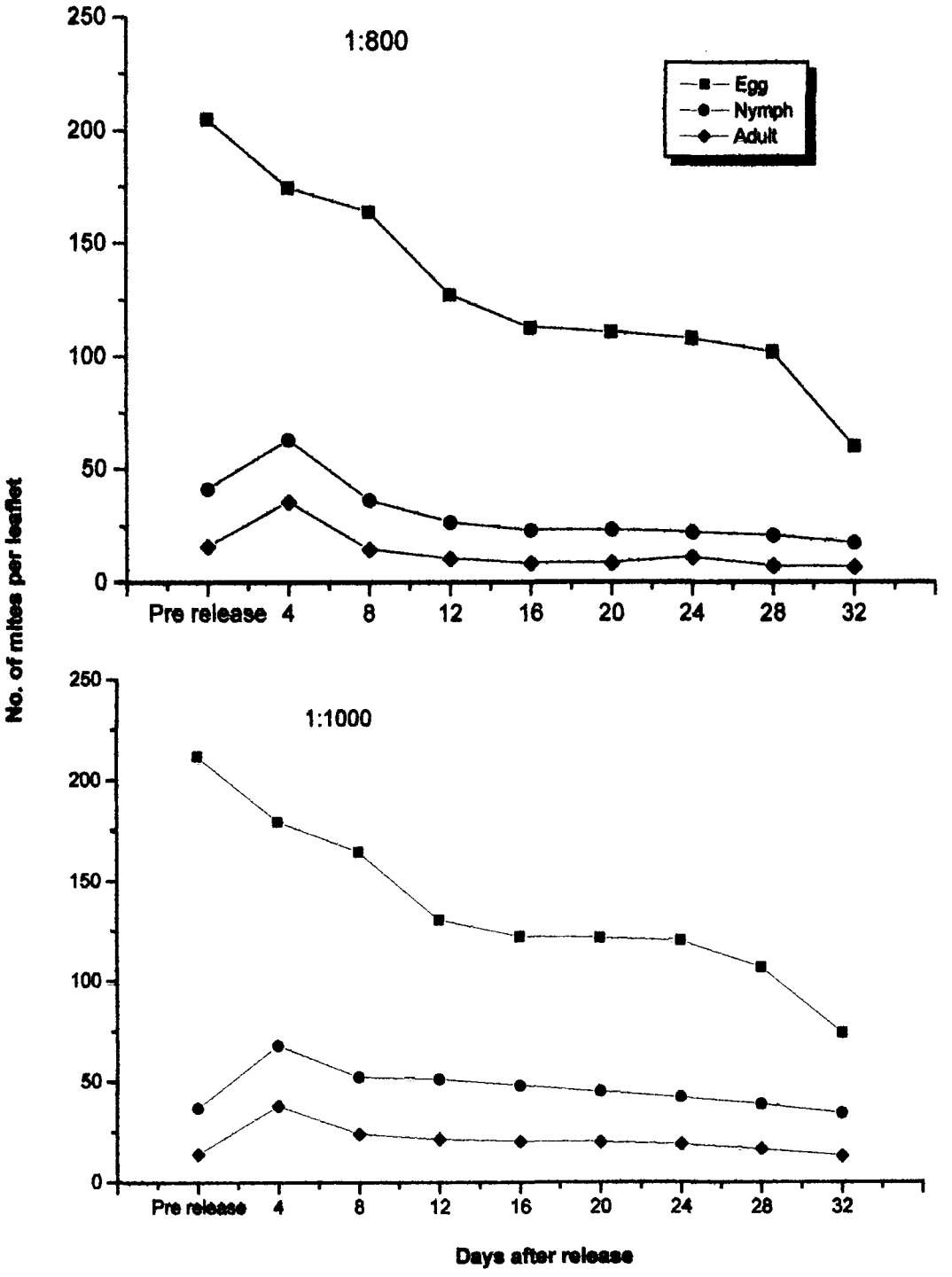

Fig. 16: Population of eggs, nymphs and adults of *T.urticae* on rose plants, where *A.longispinosus* were released at 1 : 800 and 1 : 1000 ratios.

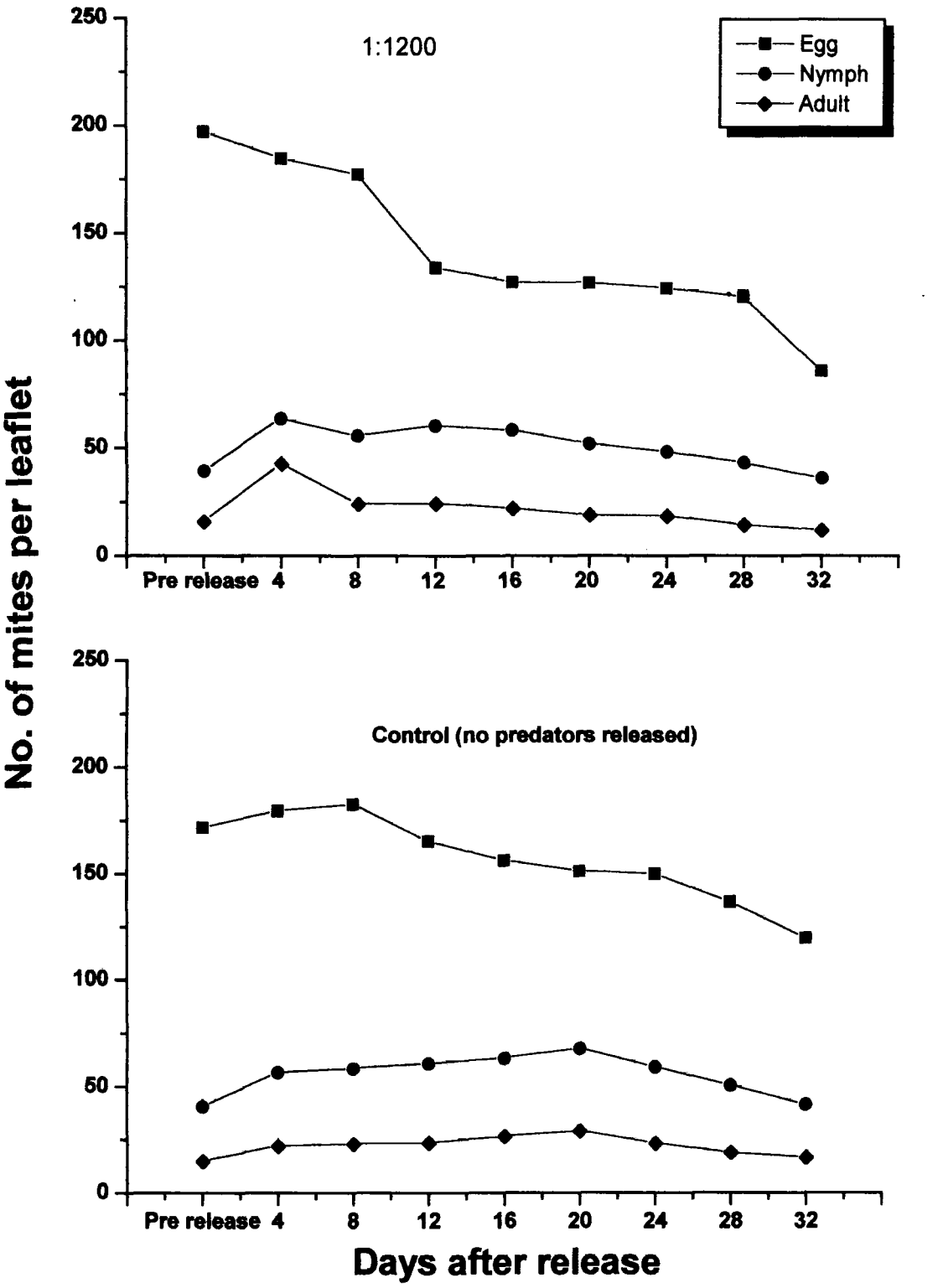

Fig. 17: Population of eggs, nymphs and adults of *T.urticae* on rose plants, where *A.longispinosus* were released at 1 : 1200 and control (no predators released)

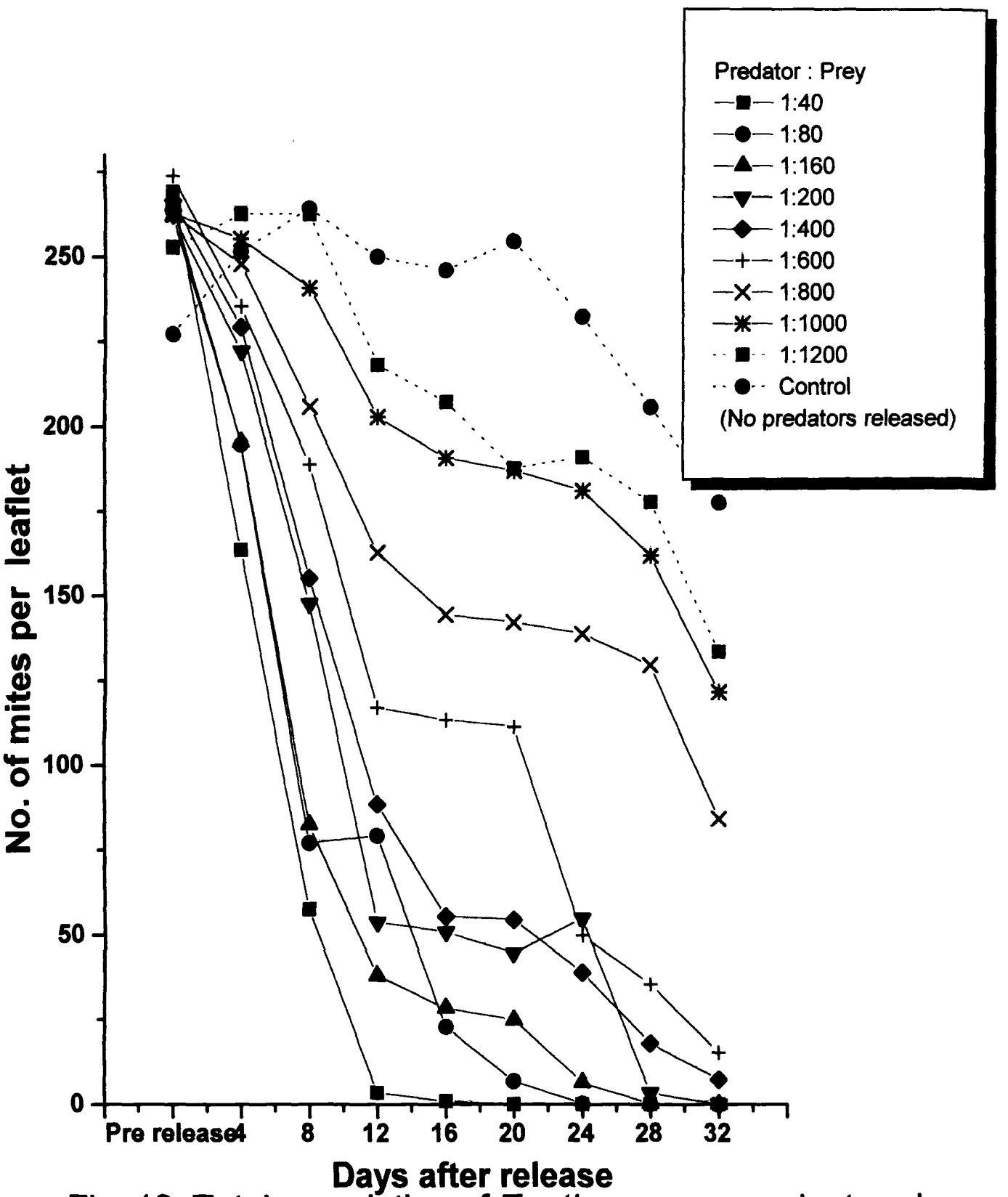

Fig. 18: Total population of *T.urticae* on rose plants, where *A.longispinosus* were released at different ratios.

4.4.2 Management of *T. urticae* using chemicals

To compare the effectiveness of the predators with that of the chemicals in reducing the population of the spider mite *T. urticae,* an experiment was conducted in TransIndia Floritech, Doddaballapur, and the observations were as follows :

4.4.2.1 Eggs

In abamectin (0.0003%) treated plots the population of eggs of *T. urticae* reduced to 9.2 per leaflet eight days after spray. But later increased to 81.93 per leaflet, twenty four days after spray. In profenofos (0.02%) treated plots the number of eggs decreased to 43.72 per leaflet, eight days after spray and reached a population of 111.73 per leaflet twenty days after spray, then again declined to 104.24 per leaflet, twenty four days after spray. In dicofol (0.014%) treated plots the egg population of *T. urticae* initially declined to 57.63 per leaflet, four days after spray, then increased to 141.46 per leaflet twenty days after spray and again declined to 133.42 per leaflet. But in water sprayed control plots the egg population increased to 180.02 per leaflet, eight days after spray and later decreased to 144.24 per leaflet twenty four days after spray (Table 12, Fig. 19).

4.4.2.2 Nymphs

In abamectin (0.0003%) treated plots the nymphal population was zero one day after spray, then the population gradually increased to 34.56 per leaflet twenty days after spray, and again decreased to 27.86 per leaflet twenty four days after spray. The same trend was observed in profenofos (0.02%) treated plots the nymphal population declined to 5.44 per leaflet one day after spray. But increased to 46.36 per leaflet sixteen days after spray and later started declining. In dicofol (0.014%) treated plots the population decreased to 17.76 per leaflet one day after spray, then gradually increased to 66.50 per leaflet twelve days after spray and started declining thereafter. But in water sprayed control plots the population increased to 68.60 per leaflet twelve days after spraying, then decreased to 44.08 per leaflet twenty four days after spray (Table 13, Fig. 19).

Table 12: Effect of abamectin, profenofos and dicofol on the eggs of *T. urticae* on rose at TransIndia polyhouse.

Treatments	Number of eggs per leaflet							
	Before spray	1DAS	4DAS	8DAS	12DAS	16DAS	20 DAS	24DAS
Abamectin (0.0003%)	150.07 (12.26)	138.26[a] (11.78)	35.18[a] (5.97)	9.20[a] (3.09)	42.39[a] (6.54)	65.70[a] (8.13)	75.53[a] (8.72)	81.93[a] (9.10)
Profenofos (0.02%)	165.44 (12.88)	157.04[b] (12.55)	54.56[b] (7.43)	43.72[b] (6.64)	66.54[b] (8.19)	83.51[b] (9.16)	111.73[b] (10.59)	104.24[b] (10.81)
Dicofol (0.014%)	166.25 (12.91)	158.54[b] (12.51)	57.63[b] (7.62)	90.92[c] (9.56)	107.96[c] (10.41)	156.40[c] (12.52)	141.46[c] (11.91)	133.42[c] (11.57)
Control	170.01 (13.05)	171.33[c] (13.10)	175.94[c] (13.30)	180.02[d] (13.43)	164.83[d] (12.85)	155.45[c] (12.49)	151.83[d] (12.34)	144.24[d] (12.03)

At 24 DAS: F - Test * ; CD at P = 0.05 - (0.35). Values in the parentheses are transformed [$\sqrt{(x + 0.5)}$] values.
DAS- Days After spray. Control : Water spray

Table 13: Effect of abamectin, profenofos and dicofol on the nymphs of *T.urticae* on rose at TransIndia polyhouse.

Treatments	Number of nymphs per leaflet							
	Before spray	1DAS	4DAS	8DAS	12DAS	16DAS	20 DAS	24DAS
Abamectin (0.0003%)	37.41 (6.15)	0.00[a] (0.707)	17.74[a] (4.26)	24.35[a] (4.92)	28.96[a] (5.31)	33.95[a] (6.00)	34.56[a] (5.92)	27.86[a] (5.32)
Profenofos (0.02%)	34.34 (5.89)	5.44[b] (2.43)	33.02[b] (5.79)	52.05[b] (7.25)	44.33[b] (6.70)	46.36[b] (6.85)	39.35[a] (6.31)	34.70[b] (6.66)
Dicofol (0.014%)	31.74 (5.67)	17.76[c] (4.27)	51.04[c] (7.18)	57.61[bc] (7.62)	66.50[c] (8.19)	55.68[c] (7.50)	45.22[b] (6.76)	41.81[b] (6.50)
Control	41.45 (6.47)	41.86[d] (6.50)	52.36[c] (7.27)	60.80[c] (7.70)	68.60[c] (8.31)	57.10[c] (7.59)	49.93[b] (7.10)	44.08[b] (6.60)

At 24 DAS: F - Test * ; CD at P = 0.05 - (0.41). Values in the parentheses are transformed [$\sqrt{(x + 0.5)}$] values.
DAS- Days After spray. Control : Water spray

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4.4.2.3 Adults

In abamectin (0.0003%) treated plots the adult population was reduced to zero one day after spray, but increased to 16.73 per leaflet twenty four days after spray (Table 14). Similarly in profenofos (0.02%) sprayed plots the adult population declined to 1.52 per leaflet but increased to 25.94 per leaflet twenty days after spray and later declined. In dicofol (0.014%) treated plots the population of *T. urticae* adults declined to 7.2 per leaflet one day after spray and then increased upto twenty days after spray, but later started declining. But in water sprayed control the adult population gradually increased upto sixteen days after spray then decreased to 26.40 per leaflet twenty four days after spray (Table 14, Fig. 19).

4.4.2.4 Total population of *Tetranychus urticae*

In abamectin (0.0003%) treated plots the population of all stages of *T. urticae* declined to 38.44 per leaflet eight days after spray, then gradually increased to 126.52 per leaflet twenty four days after spray. In profenofos (0.02%) sprayed plots the total population was reduced to 92.11 per leaflet four days after spray, then it gradually increased to 177.02 per leaflet twenty days after spraying, later it started declining (Table 15, Fig. 19). In dicofol (0.014%) treated plots total population of all stages of *T. urticae* gradually declined to 117.15 per leaflet four days after spray, then increased to 242.58 per leaflet sixteen days after spray. In water sprayed control plots the total population increased upto 271.75 per leaflet twelve days after spray, then gradually declined to 214.72 per leaflet twenty four days after spray (Table 15, Fig. 19).

4.5 Mass production of *Amblyseius longispinosus* :

Study on production of *A. longispinosus* within a glasshouse was carried out at Department of Entomology.

For this study French bean seeds were sown in polythene covers (10 cm diameter), earthen thumb pots (14cm diameter), earthern nand pots (22cm diameter) and in the ground. In the polythene covers the seeds germinated 4.5 - 5.0 days after sowing, but

Table 14: Effect of abamectin, profenofos and dicofol on the adults of *T. urticae* on rose at TransIndia polyhouse.

Treatments	Number of adults per leaflet							
	Before spray	1DAS	4DAS	8DAS	12DAS	16DAS	20 DAS	24DAS
Abamectin (0.0003%)	10.90 (3.37)	0.00^{a} (0.707)	0.00^{a} (0.707)	4.89^{a} (2.32)	8.46^{a} (2.98)	14.31^{a} (3.84)	15.64^{a} (4.01)	16.73^{a} (4.15)
Profenofos (0.02%)	9.88 (3.21)	1.52^{a} (1.41)	4.53^{b} (2.23)	16.03^{b} (4.06)	23.00^{b} (4.84)	26.41^{b} (5.18)	25.94^{b} (5.14)	21.99^{ab} (4.74)
Dicofol (0.014%)	14.14 (3.83)	7.20^{b} (2.77)	8.48^{b} (2.99)	25.58^{c} (5.10)	28.10^{bc} (5.34)	30.50^{b} (5.56)	28.08^{b} (5.34)	22.71^{ab} (4.81)
Control	15.22 (3.96)	19.20^{d} (4.43)	22.86^{c} (4.83)	27.80^{c} (5.31)	38.32^{c} (6.23)	35.61^{b} (6.01)	30.37^{b} (5.55)	26.40^{b} (5.18)

At 24 DAS: F - Test * ; CD at P = 0.05 - (0.99). Values in the parentheses are transformed [$\sqrt{(x + 0.5)}$] values.
DAS- Days After spray. Control : Water spray

Table 15: Effect of abamectin, profenofos and dicofol on the total population of *T. urticae* on rose at TransIndia polyhouse.

Treatments	Total population of *T. urticae* per leaf.							
	Before spray	**1DAS**	**4DAS**	**8DAS**	**12DAS**	**16DAS**	**20 DAS**	**24DAS**
Abamectin (0.0003%)	198.38 (14.10)	138.26[a] (11.78)	52.92[a] (7.31)	38.44[a] (6.23)	79.61[a] (8.89)	115.93[a] (10.78)	125.73[a] (11.23)	126.52[a] (11.27)
Profenofos (0.02%)	209.60 (14.49)	164.00[b] (12.82)	92.11[b] (9.63)	111.80[b] (10.59)	133.87[b] (11.59)	156.28[b] (12.52)	177.02[b] (13.32)	160.92[b] (13.56)
Dicofol (0.014%)	212.09 (14.58)	183.50[c] (13.48)	117.15[c] (10.85)	174.11[c] (13.21)	202.56[c] (14.25)	242.58[c] (15.59)	214.96[c] (14.67)	197.94[c] (14.09)
Control	226.68 (15.07)	232.49[d] (15.26)	251.13[d] (15.88)	268.62[d] (16.34)	271.75[d] (16.50)	240.99[d] (15.77)	232.13[d] (15.25)	214.72[d] (14.66)

At 24 DAS: F - Test * ; CD at P = 0.05 - (0.35). Values in the parentheses are transformed [$\sqrt{(x + 0.5)}$] values.
DAS- Days After spray. Control : Water spray

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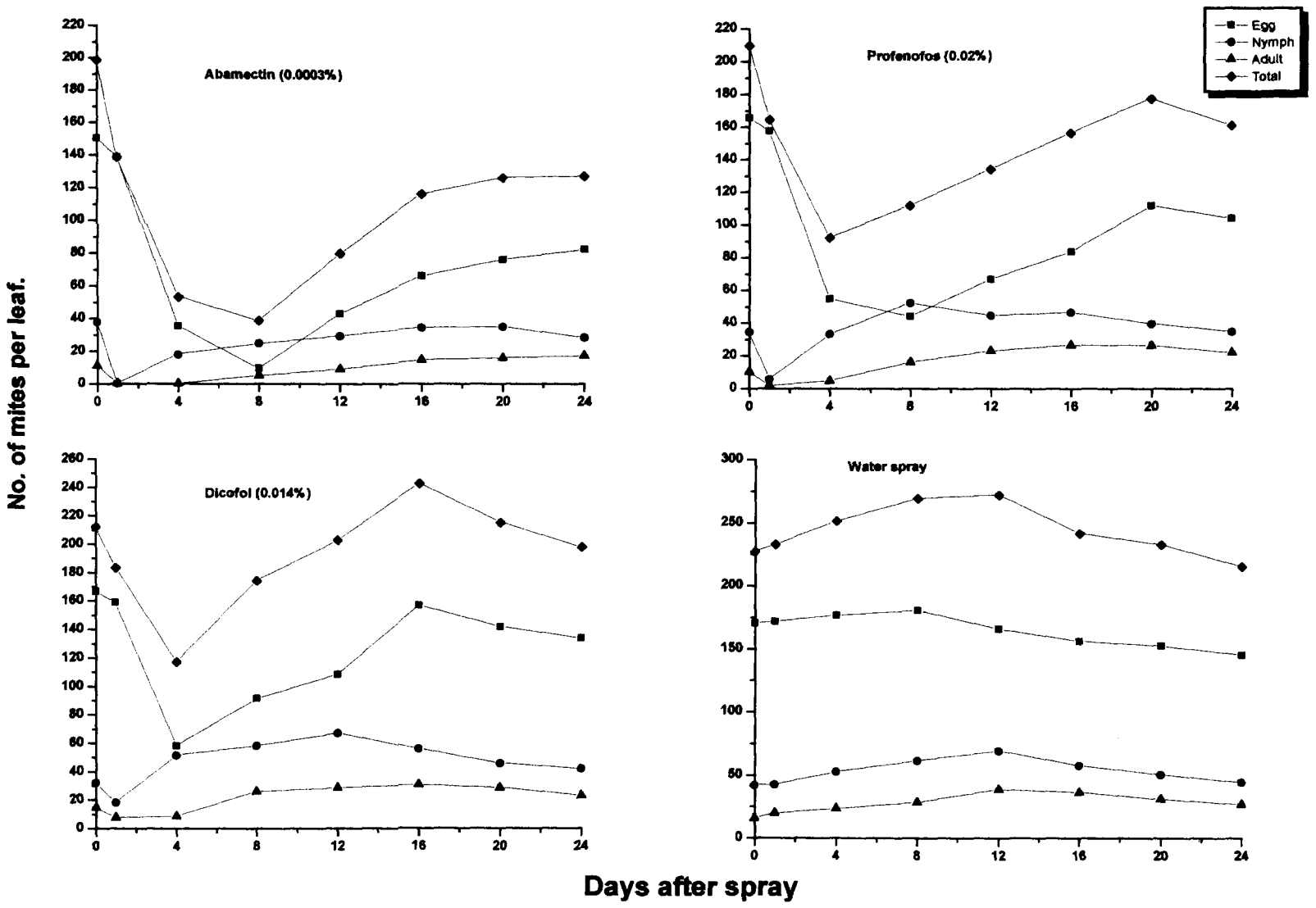

Fig. 19: Effect of abamectin, profenofos, dicofol and water spray (control) on different stages of *T. urticae* on rose.

further growth and development was very poor, seedlings were lanky. The average leaf area (l = 6.5 - 7.0 cm. x b = 5.5 - 6.0 cm.) was also less. In earthen thumb pots the seeds germinated six days after sowing, growth and development of the plant was poor in thumb pots than in nand pots. In thumb pots leaf area was l = 7.0 - 7.5 cm. x b = 8.5 - 9.0 cm. In the ground the germination of seeds was observed five days after sowing, twelve days after sowing, plants attained nine leaflets stage, here the leaf area was on par with the leaf area of plants grown in nand pots (l = 15.0 cm. x b = 11.0 cm.), but the leaves were affected by powdery mildew frequently. In nand pots germination of seeds was observed five days after sowing and the leaf area was more compared to plants grown by above methods (l = 15.5 cm. x b = 11.5 cm.), plants were healthy and no lanky growth of seedlings was observed. Hence further studies were continued in plants grown in 22cm diameter pots (nand pots).

4.5.1 Population development of *Tetranychus urticae*

Development of *T. urticae* population on French bean plants was studied on three different sets of plants raised in different months. In the first batch twelve days after sowing fifteen plants were infested with 3,200 eggs, 2,850 nymphs and 1,900 adults of *T. urticae* collected from a pure culture maintained in the glass house. Thereafter observations on mites were recorded once every three days, total number of leaflets per plant was also recorded (Table 16). The population of *T. urticae* increased to 378.93 mites per leaflet eighteen days after release and later declined. Upto thirtythree days after sowing the number of leaflets increased, then decreased. In the second batch, twelve days after sowing 3,500 eggs, 2,900 nymphs and 2,000 adults of *T. urticae* were released. The total population (all stages) of *T. urticae* reached a peak of 401.10 per leaflet fifteen days after release and eighteen days after release the population of *T. urticae* gradually decreased to 242.80 per leaflet thirty days after release. In the third batch the seedlings were infested with 3,400 eggs, 3,000 nymphs and 2,000 adults, twelve after sowing when they were in nine leaflets stage. Eighteen days after infestation with *T. urticae* the population reached a peak of 416.60 per leaflet later the population gradually decreased to 274.3, thirty days after sowing. Thirty nine days after sowing the number of leaflets reduced to 16 per plant (Table 16). Between the three batches of plants, there was no

Table 16: Development of population of *T. urticae* on French bean plants in the glass house and growth pattern of French bean plants.

Days after release of prey	I Batch		II Batch		III Batch	
	Total population of prey per leaflet	No. of leaflets on French bean plants	Total population of prey per leaflet	No. of leaflets on French bean plants	Total population of prey per leaflet	No. of leaflets on French bean plants
3	46.06	9	72.2	9	73.6	9
6	97.66	9	181.00	9	180.5	9
9	229.19	12	329.2	12	341.2	12
12	240.99	12	386.76	12	399.95	12
15	370.00	15	401.1	15	410.21	15
18	378.93	15	396.8	15	416.6	15
21	346.76	18	387.00	18	402.0	18
24	296.85	18	369.2	18	350.9	18
27	258.77	18	344.6	16	325.93	18
30	215.53	15	242.8	15	274.3	16

difference in the number of leaflets per plant. Maximum of eighteen leaflets were observed between 21 and 27 days after sowing.

4.5.2. Mass production *Amblyseius longispinosus*

To standardise the time of initial infestation of the predator and later harvest, the predators were released 9, 12, and 18 days after *T. urticae* was released on the plants.

4.5.2.1 Release of predators nine days after infestation with *Tetranychus urticae*

Nine days after infestation with *T. urticae*, 250 adult females of *A. longispinosus* were released. Every three days the number of different stages of the predator and the prey was recorded. Population of the predator increased from 5.32 per leaflet, three days after release to 17.46 per leaflet twelve days after release. However, fifteen days after release of predator its population started declining. The population of all stages of the prey decreased from three days after release of the predators (Table 17). Peak in the population of the predators was recorded twelve days after release.

4.5.2.2 Release of predators twelve days after infestation with *Tetranychus urticae*

Twelve days after infestation with *T. urticae*, 250 adult females of *A. longispinosus* were released. Every three days the number of different stages of the predator and the prey was recorded. Population of the predator increased from 3.85 per leaflet three days after release to 15.25 per leaflet ten days after release, however, twelve days after release, its population started declining. The population of all stages of the prey decreased from six days after release of the predator (Table 17). Peak in the population of the predator was recorded ten days after release.

4.5.2.3 Release of predators fifteen days after infestation with *Tetranychus urticae*

Fifteen days after infestation with *T. urticae*, 250 adult females of *A. longispinosus* were released. Every three days the number of different stages of the predator and the prey was recorded. Population of the predator increased from 4.45 per leaflet three days after

Table17: Population of *A. longispinosus* (number per leaflet) released at different time intervals on French bean plants infested with *T. urticae*

Days after release of the predator	Time of release of predator after release of prey							
	9 Days		12 Days		15 Days		18 Days	
	Predator (E+N+A)	Prey (E+N+A)	Predator (E+N+A)	Prey (E+N+A)	Predator (E+N+A)	Prey (E+N+A)	Predator (E+N+A)	Prey (E+N+A)
0	0	130.74	0	114.05	0	124.93	0	110.85
3	5.32	142.23	3.85	125.82	4.45	127.86	4.26	95.19
6	13.92	131.86	11.12	125.93	10.86	117.92	8.73	78.59
9	16.46	102.9	15.25	109.66	14.26	102.79	11.12	65.13
12	17.46	84.36	15.03	95.25	11.39	85.73	9.00	46.66
15	11.76	68.53	11.39	78.99	8.32	70.06	5.93	28.93
18	7.49	36.99	7.26	59.85	4.86	32.72	1.96	9.76
21	3.59	23.86	4.26	43.25	1.46	7.72	0.8	0.1
24	1.06	11.05	1.23	18.33	0.8	1.40	0	0
27	0.21	1.69	0.8	0	0	0	0	0
30	0.13	0	0	0	0	0	0	0

E = Egg; N = Nymph; A = Adults.

release to 14.26 per leaflet nine days after release. However, twelve days after release of the predator its population started declining. The population of all stages of the prey decreased from three days after release of the predators (Table 17). Peak in the population of the predators was recorded nine days after release.

4.5.2.4 Release of predators eighteen days after infestation with *Tetranychus urticae*

Eighteen days after infestation with *T. urticae*, 250 adult females of *A. longispinosus* were released. Every three days the number of different stages of the predator and the prey was recorded. Population of the predator increased from 4.26 per leaflet three days after release to 11.12 per leaflet nine days after release. However, twelve days after release of the predator its population started declining. The population of all stages of the prey decreased from three days after release of the predators (Table 17). Peak in the population of the predators was recorded nine days after release.

4.5.3 Estimation of yield of predators

4.5.3.1 Release of predators nine days after infestation with *Tetranychus urticae*

Twelve days after sowing, the seedlings were infested with *T. urticae* and nine days later, 250 adult female predators were released. The population of all stages of predator reached a peak twelve days after they were released (Table 18, Fig. 20-21). At the this peak stage 8.33 eggs, 5.33 nymphs and 3.80 adults of the predator per leaflet were recorded, and each plant an average had eighteen leaflets. At this peak population stage, from the fifteen plants 2,249.10 eggs, 1,439.10 nymphs and 1,026 adults were harvested. Thus a total of 4,714.20 of all the stages of the predator were harvestable from fifteen plants.

4.5.3.2 Release of predators twelve days after infestation with *Tetranychus urticae*

Twelve days after sowing, the seedlings were infested with *T. urticae* and twelve days later, 250 adult female predators were released. The population of all stages of the

predator reached a peak ten days after they were released. At this peak stage 7.26eggs, 4.93 nymphs and 3.06 adults of the predator per leaflet were recorded, and each plant on an average had eighteen leaflets (Table 18, Fig. 20-21). At this peak population stage, from the fifteen plants 1,960.20 eggs, 1,331.10 nymphs and 826.20 adults were harvested. A total of 4,117.50 of all the stages of the predator were harvestable from fifteen plants.

4.5.3.3 Release of predators fifteen days after infestation with *Tetranychus urticae*

Twelve days after sowing, the bean seedlings were infested with *T. urticae* and fifteen days later, 250 adult female predators were released. The population of all stages of the predator reached a peak nine days after they were released (Table 18, Fig. 20-21). At this peak stage 6.80 eggs, 4.60 nymphs and 2.86 adults of the predator per leaflet were recorded, and each plant on an average had eighteen leaflets. At this peak population stage, from the fifteen plants 1,836.00 eggs, 1,242.00 nymphs and 772.20 adults were harvested. A total of 3,850.20 of all stages of the predator were harvestable from fifteen plants.

4.5.3.4 Release of predators eighteen days after infestation with *Tetranychus urticae*

Twelve days after sowing, the bean seedlings were infested with *T. urticae* and eighteen days later, 250 adult female predators were released. The population of all stages of the predator reached a peak nine days after they were released (Table 18, Fig. 20-21). At the this peak stage 5.60 eggs, 3.06 nymphs and 2.46 adults of the predator per leaflet were recorded, and each plant on an average had eighteen leaflets. Further at this peak population stage, from the fifteen plants 1,512.00 eggs, 826.20 nymphs and 664.20 adults were harvested. Thus a total of 3,002.40 of all stages of the predator were harvestable from fifteen plants.

4.6 Cost of production of predators from fifteen plants :

These fifteen French bean plants used for the study were raised in pots of 6" diameter and these plants occupied 1.5 m^2 cement platform area inside the glass house.

Table 18: Number of different stages of *Amblyseius longispinosus* which can be harvested at its peak population from 15 plants when infested after different periods of prey development.

Predator released DAS	Time(days) taken by the predator to reach peak population after their release	Number of predators per leaflet at peak population				Harvestable number of predators from 15 plants			
		Egg	Nymph	Adult	Total	Egg	Nymph	Adult	Total
21	12	8.33	5.33	3.80	17.46	2249.10	1439.10	1026.00	4714.20
24	10	7.26	4.93	3.06	15.25	1960.20	1331.10	826.20	4117.50
27	9	6.80	4.60	2.86	14.26	1836.00	1242.00	772.20	3850.20
30	9	5.60	3.06	2.46	11.12	1512.00	826.20	664.20	3002.40

DAS = Days after sowing. * Plants were infested with *T. urticae* 12 days after sowing.

** Each plant had 18 leaflets at peak predator population.

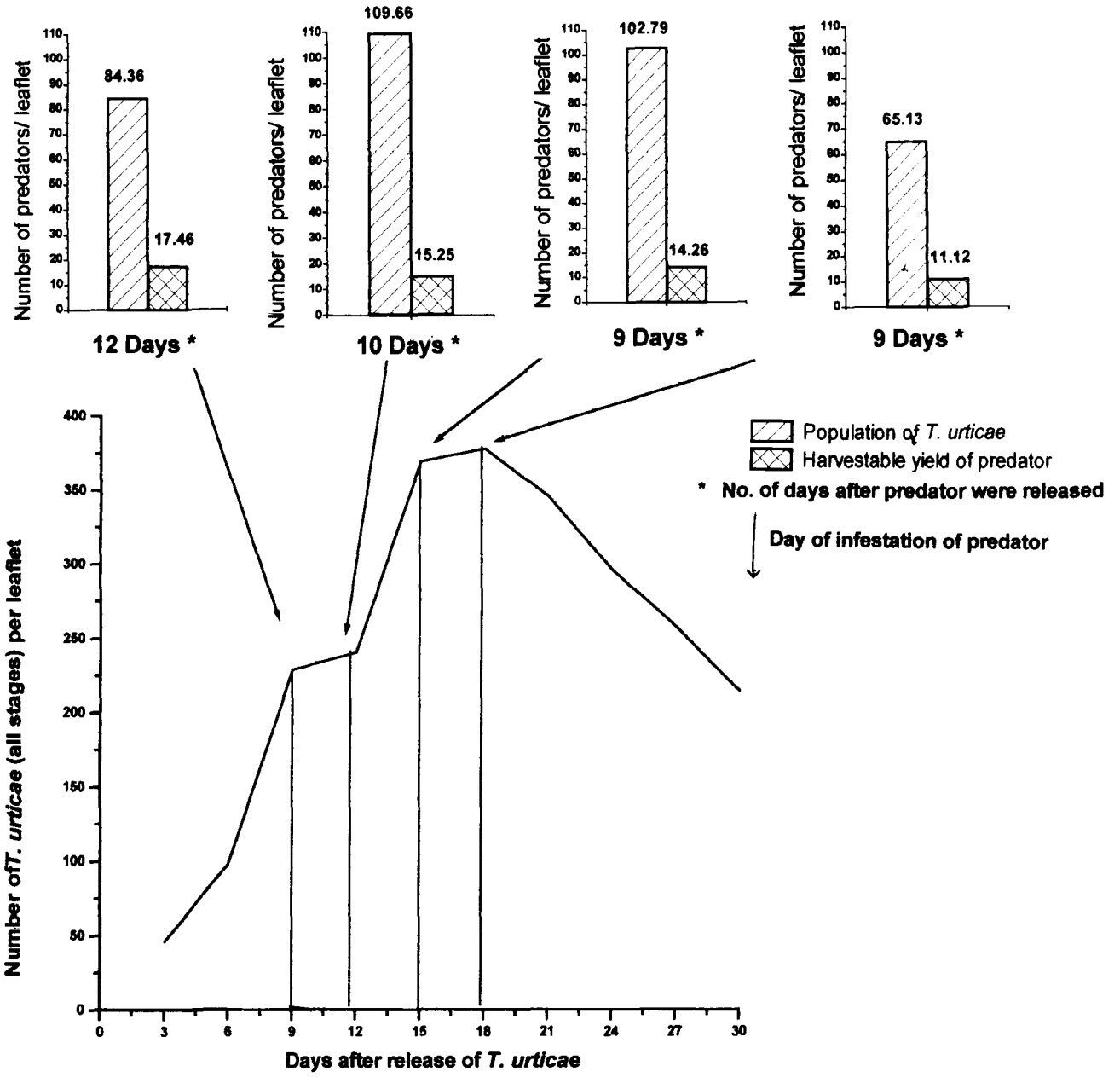

Fig. 20. Harvestable yield of predators at its peak population in relation to infestation time and population level of *T.urticae*

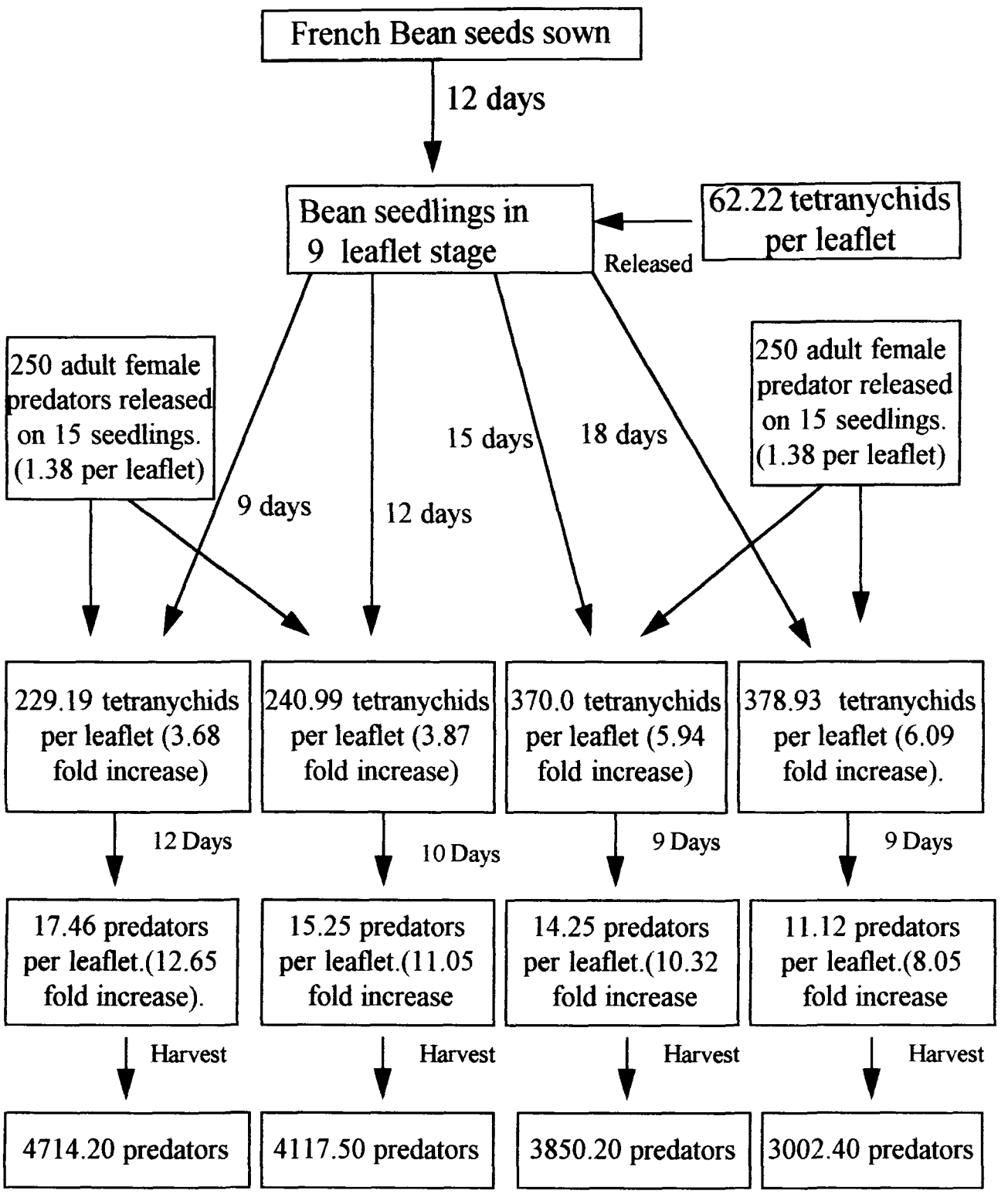

Fig. 21: Mass multiplication of *A. longispinosus* on *T. urticae* infested French bean plants

Sl. No.	Materials	Quantity	Cost	Total Cost Rs.
1	Pots of 6 inches diameter	15	Rs. 8 /pot	2=00*
2	Vermicompost	2 kg.	Rs. 2.5/ kg	5=00
3	Fertiliser 15:15:15	100 gms	Rs. 10 /kg	1=00
4	Bean seeds	25 gms.	Rs. 60 /kg	1=50
5	Water charge	4 liter per day	-	20=00
6	Labour charge	2 man days	Rs. 50 /day	100=00
7	Glass house rent for 1.5m^2 area	-	Rs. 9 /month	9=00

Total = Rs. 138=50 /month

* A pot can be used for five years. In these five years sixty batches of beans can be raised. So the cost of a single pot will be around Rs.2.00.

From 15 plants, 4714.2 mites were harvested, the cost of production for these predators was Rs.138.50, thus cost of producing one predator was two paise. The entire glass house (50m^2) could accommodate 300 bean plants, which can be used for raising 94,284 predators and the total cost will be Rs.2,820.

DISCUSSION

V DISCUSSION

The spider mite, *Tetranychus urticae,* is an important pest of rose and many other crops, but information in India on aspects like biological control is entirely absent. The present investigation was oriented towards the basic aspects of biological control of *T. urticae* using the predatory mite *Amblyseius longispinosus* like dispersal of the predator and mass multiplication of the predator *etc.*

5.1 Distribution of *Tetranychus urticae* on rose in polyhouse :

At all canopy levels, the distribution of eggs, nymphs and adults of the *T. urticae* had a similar pattern. The population of eggs, nymphs and adults was highest on middle canopy of the rose plant compared to top and bottom canopy levels. Within each compound leaf the terminal leaflet harboured more number of mites followed by next pair of leaflets (L1 and R1) and bottom leaflets (L2 and R2).

Krainacker and Carey (1990) observed that aggregation of *T. urticae* was on lower leaves of the corn plant early in the season and on the mid plant leaves towards the end of the season. They suggested that mites sampling should focus on the number of females on the lower leaves , early in the season and on the middle leaves during the end of the season. Annon. (1998) has similarly reported that aggregation of *T. urticae* was more on middle leaves of the bean plants followed by bottom leaves. Onkarappa (1999) reported the aggregation of *T. urticae* on lower leaves of the rose plants grown in the open field conditions. He opined that rose being a shrub the senescence of the leaves is much slower than in annuals like French bean hence, the lower leaves are preferred by the mite. In polyhouse regular pruning of the shoots is a common practice. The growth of the rose plants within a polyhouse is faster compared to plants in the open, hence the bottom leaves attains senescence early, as a result the mites avoid the bottom leaves and prefer the middle leaves. The top leaves being secculent are less preferred. The mean number of eggs, nymphs and adults per leaflet on leaves of bottom, middle and top canopy was less than the variance. It was clear that the distribution was clumped. The population of different stages of the mite in the leaflets of the top canopy leaves had high coefficient of variance and the correlation value with the total population was low, whereas the population of

different stages of the mite in the leaflets of the bottom canopy leaves had low variance and low correlation value with the total population. However, the population of different stages of the mite in the leaflets of middle canopy leaves had low coefficient of variance and high correlation value with the total population. Sampling should be focussed on the leaves/leaflets having low variance and high correlation with total population. The terminal leaflet of the middle leaf had high correlation value and low variance compared to other leaflets, hence this leaflet forms the most appropriate sample for future sampling program.

5.2 Functional and numerical responses of *Amblyseius longispinosus* :

It is evident from the data that as the density of prey (*T. urticae*) increased (upto 80 eggs per leaf), there was curvilinear relationship between the density of the prey eggs and number of prey eggs consumed by *Amblyseius longispinosus.* This is type II response curve. The consumption rate increased from 8 eggs per day at a prey density of 10 eggs per leaf bit to 41.4 eggs per day at a prey density of 80 eggs.

The number of eggs laid by the predator increased from 1.4 eggs per day at prey eggs density of the 10 per leaflet to 5.4 eggs per day at prey egg density of 70 per leaflets. Which remained same even when the density increased to 80 eggs per leaf. The numerical response curve also showed a curvilinear rise attaining a plateau after the density of 60 prey eggs, however a decline in the response at higher prey densities observed in the study might be mainly due to high variance in the results.

Sandness and McMurtry (1970) reported that the functional response of *Amblyseius largoensis* and *A. concordis* to densities of *Oligonychus punicae* was curvilinear, the rise was observed almost upto a predator-prey ratio of 1: 200. The number of contacts between the predator and the prey increased with prey density. In the present study also the functional response of *A. longispinosus* was curvilinear, but the rise in the curve was seen only upto predator-prey ratio of 1:60. The number it killed increased from 8 eggs per day at a prey density of 10 mites to approximately 41.4 eggs per day at a prey density of 80 and numerical response increased from 1.4 eggs per day at a prey density of 10 eggs to 5.4 eggs per day at a prey density of 80. *A. longispinosus* has high predatory

potential than *Amblyseius chilensis.* Laing and Osborn (1974) observed that the number of prey killed by *A. chilensis* increased from 6.2 mites per day at a prey density of 10 to approximately 13.5 mites per day at a prey density of 210 and the numerical response increased rapidly from 1.6 eggs per day at a prey density of 10 mites to a gradually rising plateau lying between 2.4 eggs at a prey density of 40 mites and 2.8 eggs per day at a prey density of 210.

Anil (1990) reported on the functional and numerical responses of *A. longispinosus* to the eggs of *Oligonychus indicus.* The functional response rose from 14.4 eggs per predator per day at a prey density of 15 eggs per leaf bit to 22 prey killed per predator per day at a prey density of 35 eggs and was same at 40 eggs per leaf bit, whereas the numerical response curve rose from 1.5 eggs laid per predator per day at 15 eggs per leaf bit to 3.0 eggs laid per predator per day at 35 eggs leaf bit. Whereas in the present study the functional response rose from 8 eggs killed per predator per day at prey density of 10 eggs per leaf bit to 41.4 prey killed per predator per day at a prey density of 80 eggs. Whereas the numerical response curve rose from 1.40 eggs laid per predator per day at 10 prey eggs per leaf bit to 5.4 eggs laid per predator per day at 70 eggs per leaf bit and was the same at 80 eggs per leaf bit.

5.3 Dispersal of *Amblyseius longispinosus* :

One week after release of predators they were recorded only at the point of release, the predator dispersed upto one meter distance in two weeks time. Similarly three, four and five weeks after release the predators were collected three, six and ten metres respectively from the point of release. This movement is relatively slower compared to that reported for *Phytoseiulus persimilis* on chrysenthamum by van de Vrie (1985). This predator was observed to move upto 15 metres in one week. Several factors can affect the movement, the two major being prey density and wind. Prey density can be neutralised by the number of predator released and in situations like plants grown under cover, the role of wind is minimal. Hence other parameters like plant architecture, plant density, soil conditions etc., become important. In the present study the soil used to be moist through out since, the plants were watered by drip system, and no time the soil was flooded with water, which would be otherwise detrimental to predator moving on the ground. The plant

architecture and plant density appears to be important parameters for the difference between the two species. Chrysanthamum has dense foliage and the plant density is usually high, hence the foliage of the adjoining plants will be close to each other, aiding easy movement of the predators. But in the rose plants grown under cover, the plants are not densely planted, nor is the plant architecture such that the leaves are close to each other, hence this must have affected the movement of *A. longispinosus.* Johnson and Croft (1981), reported the number of predators trapped at 4, 8, 19, 42 and 72 m. from the border of an apple orchard decreased exponentially, which supports the present findings, as the distance from the release point increased the number of predators recorded decreased.

5.4 Management of *Tetranychus urticae* :

5.4.1 Management using phytoseiids at different predator - prey ratios

At 1: 40 ratio, *A. longispinosus* caused maximum reduction of *T. urticae* within two weeks of release. At 1:80 ratio *A. longispinosus* caused reduction of *T. urticae* two weeks after release of the predators. Decline in eggs was more compared to other stages of the prey mite and followed by nymphs and adults, since *A. longispinosus* preferred to feed on eggs compared to nymphs and adults. Once the population of the prey mite was reduced, the population of predatory mite also declined. In control the egg, nymph and adult stages of the prey increased upto 20 days, later population of the spider mite gradually declined because of deterioration of the plant condition which was not suitable for further multiplication of the mites and also due to movement of the predatory mites from released plots to control.

In all ratios of *A. longispinosus* and *T. urticae* four days after release the number of eggs of *T. urticae* decreased, nymphal and adult population increased upto four days after release of the predators then gradually decreased in the ratios of 1:200 to 1:1200. This is because predators preferred to feed on eggs first then nymphs and adults of *T. urticae.*

Wilson *et al.* (1983) reported that *Metaseiulus occidentalis* at 1:10 ratio gave good control of *Tetranychus* sp. on almond within two weeks of release. Kongchuensin *et al.* (1998) reported that mass releases were made at two weeks intervals for seven times

at the rate of 2-5 predators per strawberry plant. Spider mite population was 172.64 mites per leaflet in the check but 57.86 mites per leaflet in the released plots. In the present study such frequent releases were not required since the rose plants were grown in enclosed situations.

Stenseth (1988) reported the predators (*P. persimilis*) were released in mid April at 5-10 predators per m^2 plant mass (Chrysanthamum). The number of plants infested with spider mites were reduced from 30 to zero in 45 days, whereas in the present study, 1000, 500, 250, 200, 100, 67, 50, 40 and 34 predators per m^2 plant mass (rose) were released. In 1000 and 500 predators per m^2 plant mass released plots maximum mortality of the spider mites were found within two weeks of release of the predators. In 250, 200, 100, 67, 50, 40 and 34 predators per m^2 plant mass released plots the population of the spider mite was reduced 24-32 days after release of the predators. Kilincer *et al.* (1992) reported good control of *Tetranychus* sp. on rose by releasing 15, 16, 20 and 40 predators (*P. persimilis*) per plant, whereas in the present study 13, 25, 32, 63 and 125 *A. longispinosus* per plant were sufficient. Thus *A. longispinosus* is as efficient a predator as *P. persimilis*.

5.4.2 Management using Chemicals

Abamectin (0.0003%) was most effective compared to other chemicals used. Aguiar *et al.* (1993) reported that effective control was achieved using abamectin at 20ml/100 lit. which supports the present findings. Green *et al.* (1985) obtained effective control of spider mites using higher concentration of 4.5 ppm (0.00045%).

Profenofos (0.002%) gave moderate control during present study. This is similar to the findings of Murega and Khaemba (1985) who reported moderate control of *Tetranychus* sp. by profenofos (500 g.a.i/ha) on cotton.

Dicofol (0.014%) was less effective compared to abamectin (0.0003%) and profenofos (0.02%). Pokharkar *et al.* (1986) reported that dicofol at 0.05% was less effective on open cultivated rose, this supports the present findings.

5.4.3 Effectiveness of predators *vis a vis* chemicals in controlling *Tetranychus urticae*

In abamectin (0.0003%) and profenofos (0.02%) treated plants the nymphal and adult population decreased one day after spray but gradually increased later, upto 24 days. Whereas, in predator released plots the egg, nymph and adult population of the prey gradually decreased and maximum reduction was observed twenty four days after release. Chemicals are less effective against egg stage of the spider mite, but the predators preferred the egg stage to feed.

5.5 Mass production of predators :

5.5.1 Population development of *Tetranychus urticae*

Beans plants raised in pots of 22 cm. diameter was selected for study because the leaf area of these seedlings were more and plant were healthy compared to seedlings grown in ground and polyethylene covers (10 cm. diameter). The drawback of growing beans in ground was development of powdery mildew which would affect the growth of prey population. The development of powdery mildew was mainly because of higher soil moisture. In polyethylene covers (10 cm. diameter), thumb pot (14 cm. diameter) the seedlings became lanky and lodging of the seedlings was also observed.

Seedlings attained nine leaflet stage twelve days after sowing, this stage was found to be most suitable for infesting them with *T. urticae.* If the infestation of *T. urticae* is made at six leaflets stage further growth and development of the plant is affected, whereas if infested later, out put of prey population will be low and consequently the out put of number of predators will be reduced. Nine, twelve, fifteen and eighteen days after infestation of the seedlings with *T. urticae* the predators were released. Among these, when the predators were released nine days after infestation, peak in their population was observed twelve days later, the number that would be available if harvested at this peak was higher, than when releasing of the predators was delayed. In the present study, time of spider mite infestation to bean seedlings, inoculation of predators and time of harvest of the predators was standardised. Similar data are not available in literature. Koppert (1980) has suggested that the predator, *P. persimilis* should be released as soon as distinct spider mite aggregations are noticed. Similarly Hoy *et al.* (1982) reported the large scale

rearing of *Typhlodromus occidentalis* (Nesbit) on *T. urticae* in green house. Pure culture of spider mites and mixed culture of spider mites and predators were maintained. As soon as the spider mite population reduced below 20 mites per 1 predator, the *T. urticae* infested plants from the pure culture was cut and placed over the mixed culture to augment the prey population. If the spider mite population was above 50 mites per predator a low concentration of propargite (0.33-0.66 g 30 wp omite/l.) was sprayed. Ideal time for harvesting predators was shortly after four weeks after infestation.

5.6 Cost of production of predators :

A polyhouse covering one hectare area will have 70,000 rose plants. If the prey density is medium, ten predators per plant will be sufficient to control the prey population in one month. Seven lakh predators are required for one polyhouse, the cost of this will be Rs.14,000. This is less than the cost of spraying once with abamectin (0.0003%). Though a day after spraying with abamectin the population of the prey is reduced, later it gradually increases, whereas on plants where predators are released prey population gradually decreases from the day of release of the predators and remains at a low level for a longer duration.

SUMMARY

VI SUMMARY

The present investigations were conducted to know the sampling method for the spider mite infesting rose in polyhouses, functional and numerical responses of *Amblyseius longispinosus* feeding on *Tetranychus urticae*, dispersal of *A. longispinosus* and to assess the number of *A. longispinosus* required to control the prey *T. urticae*. Comparative effectiveness of chemicals and predators in controlling prey population has also been studied. Large scale production of the predators was tried. The studies were conducted at TransIndia Floreitech, Doddaballapur and glass house of Department of Entomology, Bangalore during 1998-99. The results of the investigations are summarised below.

Egg, nymph and adult stages of *T. urticae* was comparatively more on the leaves of middle canopy compared to bottom and top canopy leaves. Terminal leaflet of the compound leaf harboured more number of eggs, nymphs and adult stages of *T. urticae* compared to remaining leaflets in a compound leaf.

There was a curvilinear relationship between density of the prey eggs and number of prey eggs consumed by the predator, this being a type-II response curve. The numerical response curve also followed a curvilinear rise attaining a plateau.

Inside the polyhouse at a mean temperature of 38-39^0 C and RH of 65-70 per cent, *A. longispinosus* dispersed upto ten metres in five weeks. First week after release they were found around the point of release (0 metre) and in two, three, four and five weeks the predators dispersed one, three, six and ten metres, respectively.

A. longispinosus caused maximum reduction of *T. urticae* within two weeks of release, when they were released at a ratio of 1:40. In 1:80 ratio of predator-prey maximum reduction of *T. urticae* was observed twenty days after release of the predators. In the ratios of 1:160, 1:200 and 1:400 maximum reduction in the population of *T. urticae* was observed 24, 28 and 32 days after release of *A. longispinosus*. In ratios of 1:600, 1:800, 1:1000 and 1:1200 population of *T. urticae* gradually decreased and to a minimum thirtytwo days after release of predators.

Abamectin (0.0003%) was very effective against nymphs and adults of *T. urticae.* One day after spraying the population reduced to zero, then gradually increased. Profenofos (0.02%) gave moderate control compared to abamectin (0.0003%). Dicofol (0.014%) was less effective in the polyhouse. The population again gradually started increasing, twenty four days after spray the population of spider mite reached a peak. On plants where the predators were released, population of spider mites gradually reduced and reached minimum population twenty four days after release of the predators.

Mass production of *A. longispinosus* was carried out in glass house at a temperature of 40-41^0 C and 30 per cent RH. Earthen pots of 6" diametre were found suitable for raising French bean plants. Twelve days after sowing, when the seedlings attained nine leaflet stage, they were infested with the spider mites. Releasing predators nine days later, was optimum since a total population of 4715 predators could be harvested from fifteen plants.

Cost of production of single predator inside the glass house was two paise. An one hectare polyhouse requires about seven lakh predators, costing Rs.14,000. This cost is less than the Rs.16,000, required for two sprays of abamectin (0.0003%).

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VII REFERENCES

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* Original not seen