BIOLOGICAL SUPPRESSION OF SPIDER MITE, *TETRANYCHUS URTICAE* KOCH (ACARI: TETRANYCHIDAE) ON CARNATION IN GREENHOUSE USING PREDATOR, *AMBLYSEIUS LONGISPINOSUS* EVANS (ACARI: PHYTOSEIIDAE)

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CERTIFICATE

This is to certify that the thesis entitled " Biological suppression of spider mite, *Tetranychus urticae* Koch (Acari : Tetranychidae) on carnation in greenhouse using predator, *Amblyseius longispinosus* Evans (Acari : Phytoseiidae) " Submitted by Mr. K. RAJASHEKHARAPPA for the degree of MASTER OF SCIENCES in AGRICULTURAL ENTOMOLOGY to the University of Agricultural Sciences, Bangalore, is a bonafide 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

Carnation (*Dianthus caryophyllus* L.), which belongs to the family Caryophyllaceae, is one of the important cut flowers, having good demand both in the national and international markets. It is indigenous to the Mediterranean region and has been cultivated by man for over 2000 years. It is known as a divine flower and the name 'Carnation' is believed to be derived from the Greek word 'Coronation ' since these flowers were used in decorating the crowns of Greek athletes (Bhatt, 1989).

India has made noticeable advances in production of flowers. Floriculture is estimated to cover an area of 73,536 ha with production of 3,65,685 MT of loose and 61,21,523 lakhs of cut flowers. The Netherlands plays a leading role in the world trade of floriculture followed by Columbia, Spain and Kenya.

Floriculture industry in India is mainly concentrated around major cities like Bangalore, Pune, Delhi, Hyderabad, Nasik, and Trivandrum (Narayana Gowda and Jayaprasad, 1997).

At present the cut flowers being grown for export include carnation, gerbera, rose, aster, gladiolous and chrysanthemum. In the global cut flower market, rose tops the list, followed by carnation and gladiolous. In India cultivation of roses and carnation have better prospects. Carnation is being grown on a large scale under glass or greenhouse condition in western countries like Holland, France, Italy, Germany, Kenya, Israel, etc. In India its cultivation is very much restricted and is grown in open fields and under shade nets in states like, Kashmir, Himachal Pradesh, Punjab, West Bengal, and Karnataka.

The consumption of floriculture products in the world is estimated to be of worth $ 40 million, it is growing at a rate of 10-15 per cent annually and is expected to touch $7 billion in 2000 A. D. Carnation ranks 7 th in the international cut flower market.

Modern breeding techniques have helped in obtaining attractive flower colours having greater export value. However, hybrid plants are more susceptible to pests and diseases. Among the pests, mites are the major pests in greenhouses as well as under open field conditions. Increase in pest problem has forced indiscriminate use of pesticides causing resurgence of mites. Recently in most of the greenhouses the level of resistance to dicofol and to other acaricides has been observed to be very high. Even frequent spraying has not been able to bring down the population of mites effectively, especially in greenhouses.

To overcome these limitations it has been felt that eco-friendly approaches, if properly explored, would be much safer ecologically. The utilization of natural enemies including mite predators, fungal, bacterial and viral pathogens etc., have remained unexplored. Among mite predators, phytoseiids are most promising. More than 1200 species are known from the world and 139 species have been reported from India (Gupta, 1986). Many have been found in association with tetranychids and other phytophagous mite species.

Laboratory studies have shown that some of these phytoseiids are capable of eliminating the prey within a short period of time when released in appropriate ratios (Mallik, 1974). Mass multiplication is possible though not very easy since they are obligatory predators (Anil, 1990).

Few phytoseiids like, *Phytoseiulus persimilis*, *Amblyseius fallacis* and *Typhlodromus limonichus* 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 better ability to adapt to warm temperature inside greenhouses under south Indian conditions (Mallik *et al.*, 1998). It is a promising predator, which can suppress the spider mite population. The present study was undertaken with the following objectives.

1. Developing a sampling method for *Tetranychus urticae* (Koch) on carnation
2. Estimation of loss caused due to *Tetranychus urticae* infestation
3. Management of spider mite, *Tetranychus urticae* using the predator, *Amblyseius longispinosus* Evans on different varieties of carnation.

REVIEW
OF
LITERATURE

II REVIEW OF LITERATURE

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

2.1. Sampling:

Wilson *et al.* (1983) developed a presence / absence monitoring procedure, that relates the proportion of mite infested main stem node leaves of cotton at the most infested node to the number of mites per leaf, this could be converted to an area estimate.

A sequential decision plan was developed in field studies in Idaho, in 1982, for assessing the economic status of *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 two pre harvest intervals in terms of proportion of leaves infested with ≥ 5 and ≥ 10 mites per leaf. Upper and lower critical limits of the sequential decision plan were defined by the confident interval, i = (pi) (n) ± (t) (n) [pi (1-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 different life stages of *T. urticae*, on cantaloupe in California. Counts of adult females were used to estimate the 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 conducted 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 procedure required approximately the same average sample size, 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 the plants sampled. Population of each stage increased gradually in the first month of the season, then rapidly rose to the 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 of the mites did not reach the upper leaves and the results suggested that mite sampling could focus on the number of females on lower leaves, early in the season.

The distribution and dispersion of the western orchard predatory mite, *Typhlodromus occidentalis* Nesbitt and its prey, *T.urticae* were determined on tart cherry, *Prunus cerasus* L. Taylor's power law was used to quantify relation between the mean and variance and to develop binomial sampling plans. The association between *Typhlodromus occidentalis* and *T.urticae* was statisticaly significant ($P<0.01$), but weaker than that reported for *Typhlodromus occidentalis* and *Tetranychus macdanieli* McGregor on apple in Washington (Jones, 1990).

Trichilo *et al.*, (1990) studied the relative abundance of three species of spider mites on cotton as influenced by pesticides and time of establishment. Plants were treated with either dicofol or methylparathion or permethrin to manipulate densities of spider mites, *Tetranychus* sp. within the plots, spider mites densities were also modified by inoculative releases of *Tetranychus turkestani*. Several times, throughout each season, the relative abundance (i.e., proportion) of each of three spider mite species, *T. urticae*, *T. pacificus* and *T. turkestani* were determined. In 1982, *T. pacificus* was the dominant species in all treatments with relative abundance of 0.85 in the dicofol treated plots and 0.67 in the untreated control however, *T . pacificus* was less dominant and significantly lower in relative abundance in plots treated with methylparathion (0.53) than in dicofol treated plots. Conversely, *T. turkestani* was higher in methylparathion (0.34) than in dicofol (0.13) treated plots. In 1983, trends were similar to 1982, although *T. urticae* was the dominant species in untreated control with a relative frequency of 0.49. Permethrin and dicofol had a negative impact on the relative abundance of both *T. urticae* and *T. turkestani*.

Hepworth and Macfarlane (1992 a) 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 sample were derived and an adjustment was made to account for sample not being truly random. A sampling plan was proposed to be adopted readily by growers wishing to take up integrated control of *T. urticae* on Strawberries. Following a systematic sample of 100 leaf lets, it was 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 MacFarlane (1992 b) proposed a range of expressions for the variance of estimates of pest population densities based on presence-absence samples. An equation of the form $1n(m) = a+b \ln(-\ln p)$ 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* population on strawberries and was shown to be the 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 found 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 *Panonychus 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 $\ln[-\ln(1-p(t))] = \Delta \operatorname{Ln}(m)$ where m is mean density, and the negative binomial distribution (NBD). The robustness of the sampling plans that used T = 0 was poor. Expected operating characteristic and average sample number functions for sampling plans based on the two P (T) – m models were similar. Robustness of sampling plans based on NBD improved 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*, 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 necessary to estimate the population density of females and motile stages, respectively at a 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* with a binomial method 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 100 leaflets provided a good estimate with mite densities higher than 5/leaflet. Binomial sampling was suitable when the densities of *T.urticae* were < 30 – 40 mites /leaflet at higher densities, all the leaflets were occupied. The association between *T. urticae* and its predators *A. californicus* and *A. rademacheri* when tested was 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.

Devi and Rai (1996) analysed the spatial distribution of mite *T. cinnabarinus* Boisduval and leaf hopper *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.

2.1 Management of spider mites:

2.2.1 Field release of different species of phytoseiids.

2.2.1.1 *Amblyseius aberrans* (Oudemans)

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

2.2.1.2 *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 the time of sampling per cent leaves with *P. ulmi* and per cent leaves with phytoseiids.

2.2.1.3. *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 a *O. gossypii*, until prey densities on cassava increased.

2.2.1.4 *Amblyseius limonicus* Garman

Braun *et al.* (1987) reported the effect of a *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.

2.2.1.5 *Amblyseius longispinosus* (Evans)

Ganok (1982) reported that the 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 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 four 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. Spidermites populations was 172.64 mites per leaflet in the check plot and 57.86 mites per leaf let in the predator released plot.

Onkarappa *et al.* (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 twenty one days after release of predators. Predators spread to the predator free plants, when the prey mite was exhausted on the predator released plants.

2.2.1.6 *Metaseiulus occidentalis* (Nesbitt)

Hoy (1985) reported on carbaryl - OP resistant strains of *Metaseiulus occidentalis* released at the rate of 350 females for every third tree of almond in every third row, the 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 meter row of strawberry infested with *T. urticae*, and selective sprays, gave good control.

2.2.1.7 *Phytoseiulus persimilis* (Althias-Henriot)

Kilincer *et al.* (1992) reported that release of 15, 16, 20 and 40 *Phytoseiulus persimilis* per plant on Gerbera, Tomato, 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 (*T.urticae*) density was not more than 10-15 mites per leaflet with timely release of predator *P.persimilis*, at the rate of one predator to ten prey, complete control of the pest was observed.

Workman and Martin (1985) reported the use of both chemicals and predators to control *T. urticae* on strawberry. Azinphosphomethyl and pirimicarb were sprayed at 14 days interval until 18th January, and predators (*P. persimilis*) were released on 29th February, these regulated 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 20 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 house 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 provided good control. During spring (0.01 – 0.10 T. urticae per leaf), early releases were very low as the pest developed towards the end of the cycle. In all cases *P. persimilis* proved capable of controlling *T.urticae* in the top part of the plant.

Nihoul and Van-Impe (1991) studied the control of *T. urticae* (Acari : Tetranychidae) 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. persimilis* 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 25,000 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 relative humidity 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/inch^2 and integration with acaricides was necessary. The population in the second green house reached 35 mites/ inch^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 per cent), 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 highly effective or effective in 20 plots.

Hirschberger and Kremheller (1993) studied the biological control of *Tetranychus urticae* by 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 mite in field raspberries using the predatory mite *P. persimilis* at Agassiz, British Columbia. For eight 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 spidermite, *Tetranychus urticae* (Acari : Tetranychidae). For biological control *P. persimilis* and *A.*

andersoni were 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.

2.3 Crop loss assessment :

No report is available on loss due to *Tetranychus urticae*, on Carnation. Hence, literature on spider mite injuries to other crop plants are reviewed below.

The effect of different population densities on the yield of cucumber was studied by Parr and Hussey (1962) and Hussey and Parr (1963). It was found that the yield was unaffected until leaf damage rose to a level corresponding to about 30 per cent of the total leaf area. Hussey and Parr (1965) showed that an interval of five weeks elapses between severe leaf damage and resulting decreases in the yield. The estimate was confirmed by plotting the weekly crop losses for each experimental plot against the plot damage index five weeks earlier. With a 30 week growing season and the five weeks interval between leaf damage and yield reduction, it is necessary for the mites to be controlled for 25 weeks, which could be achieved by as few as four sprays if applied properly and timed in relation to leaf damage, but even if spraying were poorly done and control was not achieved, not more than eight sprays should be needed although use of 12 sprays was a common practice.

Kuenen (1946) and Anderson (1947) reported reduction of chlorophyll and assimilation products in leaves of apple damaged by *Panonychus ulmi*.. Chapman *et al.*

(1952) found an increase of 23.1 per cent in number of apples on trees on which spider mites were controlled. Bondarenko and Asatur (1960) found a reduction of 34 per cent in leaf area in young apple trees on which a density of 75 to 85 individuals of *P.ulmi* per leaf was found. Growth of branches and trunk was also reduced.

In field experiments in apple, Unterstenhofer (1954) found 20 to 51 per cent reduction in yield in the year of attack. Van de Vrie (1956) showed that early injury reduced the weight per apple, but continuing attack had no further influence. Kolbe (1968) reported a reduction in yield of apple trees during the year of attack by 39 to 51 per cent and the carry over effect resulted in yield reduction of 32-38 per cent

Chapman *et.al.*(1952) reported reduction in chlorophyll content of apple leaves by 15-35 per cent due to *P.ulmi*. Zwick *et al.* (1976) observed reduction in leaf chlorophyll as well as fruit firmness in apple due to feeding by *P.ulmi.* while Hammer (1943) found a premature drop of young fruits.

Histological studies of leaves of apple and plum artificially infested with *P.ulmi* revealed that mites on the lower leaf surfaces did not damage the upper most layers of palisade mesophyll cells. Mites on both leaf surfaces fed on tissues close to the vein lets, damaging mesophyll and bundle sheath cells, resulting in bronzing. The infected trees were stunted drastically and the number of flower buds reduced strongly the year following the attack (Avery and Briggs, 1968a, 1968b). Avery (1962), Briggs and Avery (1968) showed that damage caused by *P.ulmi* on plum rootstalks occurs in two phases; in the first, shoot and root growth is affected, in the second the photosynthetic capacity is impaired. The high mite densities reduced the growth and low densities increased shoot extension.

The work with *P.ulmi* and *T.urticae* on Bartlett pea by Huffal and Spitzer (1950) suggested that a given level of mite days of feeding within a brief period will cause more severe leaf scorch than equal total feeding spread over a long period.

An initial infestation of 6 individuals of *T. cinnabarinus* per plant at 3 leaf stage in dwarf green beans caused insignificant damage but initial levels of 20 or 60 per plant significantly reduced the yield (Castanera and Arroya, 1979). Papaioannou and Soulioti (1979) studied the effects of *T.urticae* populations on bean. Population of 0.2, 0.5 and 1 mite per cm^2 leaf caused reductions in plant height (64-68 per cent), pod number (22-62.9 per cent), pod length (46-68 percent), number of seeds per pod (35-68 per cent) and mean seed weight (54-83 per cent).

Dhooria (1985) studied the effects of releasing the different levels of red spider mite *T.cinnabarinus* (1,2, 3, 4, 5, 10, 20, 30, 40, 50, 75 and 100 mites per plant having 3- 4 leaves) on growth of brinjal and okra plants. After different intervals of releases it was found that during May - June, population level of even one mite per brinjal plant, assumed serious proportions that hampered plant growth and affected initiation of flowers and fruit setting. However, okra plants tolerated up to 100 mites per plant without any adverse effect on growth during May- June.

Banerjee (1971) described the concept of economic threshold pertaining to mites on tea in India. Considering the conditions of fresh growth of leaves and spray applications, the threshold values for critical injury on tea plant are two to three mites / cm^2 of *O.coffeae* (Nietn.), 0.5 to 1.0 for *Brevipalpus phoenicis* (Geijskes) and three to four for *Acalypha theae* (Watt.)

Studies on damage on sorghum due to *O. indicus* was made by Puttarudraiah (1947 b). In severely infested plants the grain development was arrested and even some of the grains also turned red.

Ehler (1974) opined that the control of *O. pratensis* Banks is unnecessary during the hard dough stage unless the mites invade and web the panicum or severely weaken the plant and predispose it to stalk rot and other disease causing organisms. In the absence of precise economic thresholds, McWhorter (1976) recommended initiating control on corn when mites webbing and visible damage (silver mottling) are easily found in the middle third of the plant. Scheissing (1973) suggested applying chemicals when mite populations and webbing as well as few yellowed leaf areas were observed on the lower third of the corn plant.

Injury to plants by tetranychids is related to their method of feeding. They damage protective leaf surfaces and they may affect the stomatal guard cells, thereby increasing water loss (Bouanger, 1958), damage the palisade and spongy parenchyma cells (Mc Gregor and Mc Donough,1917 ; Kuenen, 1946 ; Blair, 1951 ; Baker and Connel, 1963 ; Avery and Briggs, 1968 a) and inject toxic substances into the plant (Leigh, 1963).

Leisering (1958; 1960) reported that *T. urticae* not only exhausted 18 - 22 cells per minute but also injected certain substances that were translocated to other regions of the plants. Avery and Briggs (1968b) through radio active tracer (14 CO_2) technique demonstrated that during *P. ulmi* feeding on plum, the radioactive material is injected by the mites and translocated from the feeding site to both roots and young shoots. Weisman (1968) also demonstrated that *T. urticae* injects some substances during the act of feeding , that dissolves the content of the cells, allowing the mite to suck them.

Doncanerday and Errant (1964 a) conducted field experiments to determine the effect of spider mite populations on yield and quality of cotton. Their experiments revealed that infestations of *Tetranychus cinnabarinus* (Boisduval) artificially established at different times of the growing season reduced the yield of seed cotton from 14 to 40 percent. In general, yield reduction was directly related to population density and duration of the infestation, spider mite injury also reduced the boll size and appeared to affect several characters of seed and lint. Their subsequent studies (Doncanerday and Errant 1964 b) to determine the effect of late season infestations of *T.atlanticus* McGregor, on cotton revealed that the total reduction in the yield of seed cotton varied from 13 to 22 per cent. They also reported that the mite infestation reduced the boll size, lowered the seed viability and impaired the lint production and the fiber maturity significantly.

Furr and pfrimmlr (1968) studied the effect of early, mid and late season infestation of the *T. telarius* on the yield of cotton. The mite counts showed no significant differences between the number of mites on the plants infested in the mid and late season but early infestation led to significantly more mites than late infestation. The yield in the control cages was not significantly different from that in cages infested late or early in season. The yield from cages infested in the mid season differed significantly from that in the control cages and from the cotton infested late in the season. There was about 35 per cent reduction in the yield compared with the control, early infestation reduced the yield by 31 per cent.

Jesitor (1976) studied the effects of infestation by *T. urticae* Koch, on green house carnations. He showed that the plant growth, quality of the flowers and life of the cut flowers were reduced. The critical threshold of infestation was about 0.5 mite per leaf

(0.006 mites / cm2 at a density of about 50 plants / m2 but the threshold may be lower in denser plantings.

Attiah *et al.* (1976) reported the effect of three levels of infestation by the spider mite *Tetranychus arabicus* on several qualities of eight varieties of Egyptian cotton. Mite infestation reduced the seed cotton yield in all varieties. The loss in yield due to mite infestation was low in naturally infested plants and increased with heavier artificial mite infestation. Infestation reduced the values of seed index. Fiber length and fiber fineness were not significantly affected but fiber strength was significantly increased with increased infestation.

Wyman *et al.*(1979) determined the effects of varying two spotted spider mite infesation levels on straw berry yield. Varying infestation levels of 0-5, 25, 75 and 100 mites / leaflet of *T. urticae* were created on the straw berry plants by application of cyhexatin, subsequent yield responses were determined, seasonal accumulation of 15597, 6261 and 6768 mite days per leaf let in the untreated controls in 1976, 1977 and 1978, respectively significantly reduced yield in comparison with cyhaexatin treated plots. No yield differences occurred between the plots with 25, 50, 75 and 100 mites / leaf let, which were created by 1-4 cyhexatin applications.

Oatman *et al.* (1981) Studied the effects of releases and varying infestation levels of *T. urticae* on fruit yield of straw berries. In winter planting, fruit yield and size were significantly higher in 20-25 density treatment level (DTL) plot than the 90-100 DTL plot. In another study there were no significant differences in mean total fruit yield and size between treatment plots but all the plots were significantly different from the untreated control (Oatman *et al* 1982).

Smith and Mozingo (1983) reported that relatively small late occurring populations of the two spotted spider mite *T. urticae* had measurable detrimental effects on the yield and values of large seeded Virginia type peanuts, and large populations occurring midway through the growing season reduced peanut yield by 2,803 Kg/ ha.

Rodriguez *et al.* (1983) in their studies on effects of mite infestation at various stages of soybean plant growth, found that early infestation reduced dry matter production the most, though late infestation also significantly reduced the dry matter.

Samilanic *et al.* (1983) reported that plant height and weight of Kentucky blue grass were significantly lower in replicates artificially infested with mites compared to that of uninfected replicates.

Welter *et al.* (1984) observed that growth and yield of almond trees were significantly reduced one season after infestation. Terminal shoot extension and mean leaf size were significantly reduced by infestations of 300 and 424 mite- days, respectively. The increase in the yield from 1979 to 1980 was significantly reduced by 424 mite- days as a result of reduced fruit set since flower initiation was not significantly affected.

Pena *et al.* (1984) described the density estimate method and damage caused by *Panonychus citri* on upper and lower leaves of cassava. On the upper leaves causing damage similar to that produced by a virus while on lower causing stippling and leaf browning. The numbermites per plant was correlated with a visual damage rating. Mite distribution over three different areas of the leaf estimated by means of a relative sampling method.

Oomen (1984) studied the effects of scarlet mite *Brevipalpus phoenicis* infestation on symptom, development and yield of tea and cinchona in the laboratory and field. In a field trial of over one year duration where the mite densities were diversified experimentally by spraying dicofol with average densities up to 30 eggs and mites per leaf. This density is proposed as a preliminary minimum threshold for control.

Kovach and Gorsuch (1985) determined the effects of *T. urticae* feeding on yield, leaf loss and bloom density of peach. Mean fruit weight and size were not reduced on trees that accumulated 852 mite-days prior to harvest, with peak densities of 105 mites / leaf. Bloom density in the following season was greater and leaf drop earlier on trees with high densities of mites. Trees with moderate densities produced a higher percentage of large fruits (>6.4 cm) and lower percentage of small fruits (<5.00 cm) compared with uninfected trees.

Murega and Khaemba (1985) investigated the effects of *Tetranychus* spp. infestation on growth and yield components of cotton. Mite damage adversely affected vegetative growth as measured by the amount of leaf and plant dry matter, number of leaves per plant, leaf surface area and mean size of the leaves which were reduced by 67.07, 48.46, 68.18 and 60.37 per cent, respectively in addition seed cotton yield was reduced by 46.93 per cent per plant due to mite injury. Seed quality was adversely affected through the reduction in their weight, oil content and viability by 9.30, 10.07 and 36.67 per cent, respectively. Lint weight (lint index) and lint ginning percentage also reduced by 15.42 and 4.5 per cent, respectively.

Hardman *et al.* (1985) studied the effects of European red mite (*Panonychus ulmi*) density on several yield components of delicious apples. Cumulative mite – days per leaf had a significant negative influence on the number of apples harvested per sampling zone suggesting interaction between fruit load and yield losses induced by mites.

Raworth (1989) determined the effect of spring infestations of *Tetranychus urticae* on raspberry yields. He detected no reduction in the yield as a function of mite-days.

Holanda *et al.*, (1992) investigated the losses caused by *Polyphagotarsonemus latus* Banks and *Tetranychus desertorum* Banks to *Phaseolus vulgaris* and *Vigna unguiculata* L. There was reduction in pod production (5.8 – 12.70%), number of seeds per pod (10.4-20.4%) and seed weight (17.90) of *P. vulgaris*. The corresponding values in *V. unguiculata* were 4.2, 4.2-15.90 and 4.5-21.04 %, respectively.

Hulchy and paspisil (1992) studied the relationship between the population densities of *Calepitrimerus vitis* Nalepa., *Colomerus vitis* Pagenstecher and *T. urticae* and fruit weight and sugar content in grapes. Significant relationship between population densities of both *Calepitrimerus vitis* and *T. urticae* in late summer and fruit weight were observed. Sugar content of fruit was influenced by mite infestation. The negative effect of *Colomerus vitis* on grape weight was not confirmed.

Cai *et al.*, (1992) studied the damage caused by *P. ulmi* and *T. viennensis* to fruit yield of apple trees. There was positive correlation between mean accumulated female mite-days and mean yield loss. In the year of damage, fruits were smaller and lighter with no decrease in number, but flower and fruit numbers were reduced in the following years.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The studies were carried out in the Acarology laboratory, Department of Entomology, College of Agriculture, University of agricultural sciences, Gandhi Krishi Vignana Kendra, Bangalore and in the greenhouses of Indo-American hybrid seeds, India (Pvt.) Ltd, Bangalore.

3.1 Distribution and Sampling of *Tetranychus urticae:*

The Studies on sampling were conducted at the Rashmi Farm of Indo- American hybrid seeds, India (Pvt.) Ltd., at Kengeri, Bangalore. The varieties of carnation selected for the study included Rirandello, Navajo, Style, Feyenoord, Desio, Grafield, Furlano and Kartina, which were being grown in a greenhouse. In each variety twenty plants from 10 x 1 M. area, were randomly selected and labeled. One leaf was randomly collected form each of the three canopy levels, i.e., top, middle and bottom canopy, of these twenty plants. The leaves were labeled and placed in separate polythene covers and brought to the laboratory, for observation under a stereobinocular microscope to record the number of eggs, nymphs and adults of *Tetranychus urticae,* on upper and lower surfaces. The number of eggs, nymphs and adults of *Tetranychus urticae* on flower buds were recorded separately.

The leaf area was recorded in all the varieties selected for the study since, the leaf area varied at different canopy levels of the plants. Then the population in an unit area 100 sq cm of the leaf was computed for all the varieties included in the study (Table 1).

Table 1. Leaf area at different canopy levels of plant of different varieties of carnation

Varieties	Canopy levels		
	Top	Middle	Bottom
Navajo	3.42	4.95	4.65
Rirandello	3.85	5.05	4.50
Feyenoord	3.15	4.80	4.28
Style	3.53	4.62	4.36
Desio	3.10	4.70	4.50
Furlano	3.60	5.20	4.95
Grafield	2.85	4.20	4.10
Kartina	2.93	4.60	4.35
Average	3.36	4.25	3.96

The data were utilized to study the distribution pattern of *Tetranychus urticae* on the leaf at different canopy levels of the carnation plant. The population of mites at different canopy levels was correlated with the total population. Mean and variance were calculated for eggs, nymphs and adults of *Tetranychus urticae* at different canopy levels of the plants.

3.2 Crop loss estimation:

The study on estimation of loss caused due to mite infestation was carried out by following two methods.

1. Grading harvested flowers
2. Studying stage related losses.

3.2.1. Grading harvested flowers

In this method the estimation of loss caused due to mite infestation was carried out in eight varieties of carnation. The varieties selected for the study included Cabaret, Grafitti, Rirandello, Navajo, Feyenoord, Desio, Grafield, Furlano and Kartina. The harvested flowers were first graded by the growers as good, medium and bad based on the quality of the flowers, in each variety. Later the population of the mite on these different grades of the flowers were recorded. Finally the crop loss in terms of money was calculated. The data were utilized to understand the relationship between the infestation levels and extent of loss caused by mites.

3.2.2 Studying stage related losses

In this method plants of different varieties having flower buds at different stages of the growth were randomly selected and tagged. The size of the flower bud was measured using vernier calipers (Table 2) and the shoots were classified into four stages *viz.*, stage I, stage II,stage III and stage IV.

Stage I = shoots with small sized bud (10.27 mm)

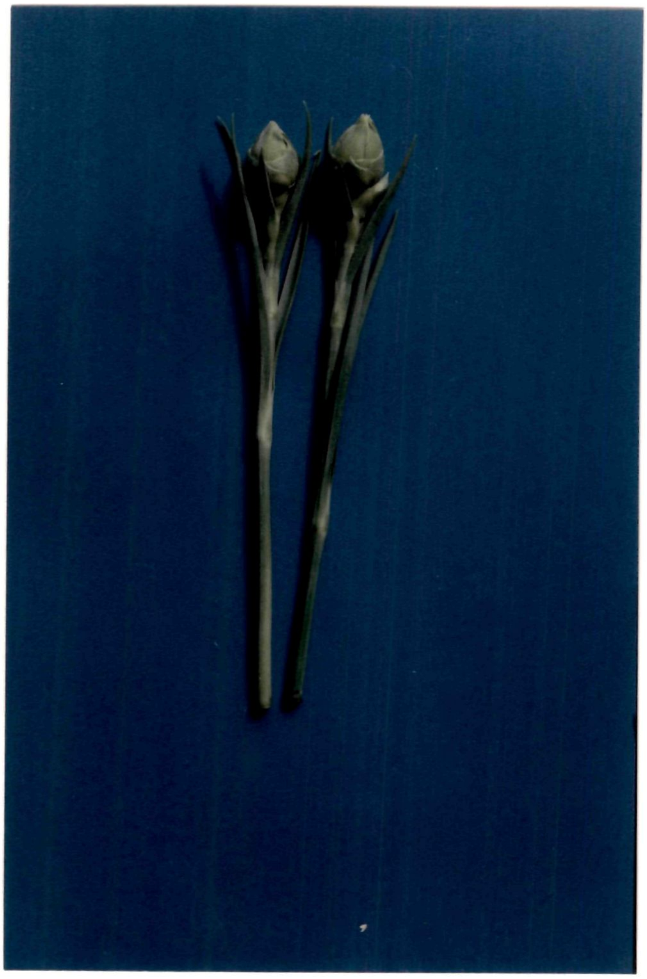
Stage II = shoots with medium sized bud (15.47

Stage III = shoots with flower bud yet to open (16.51)

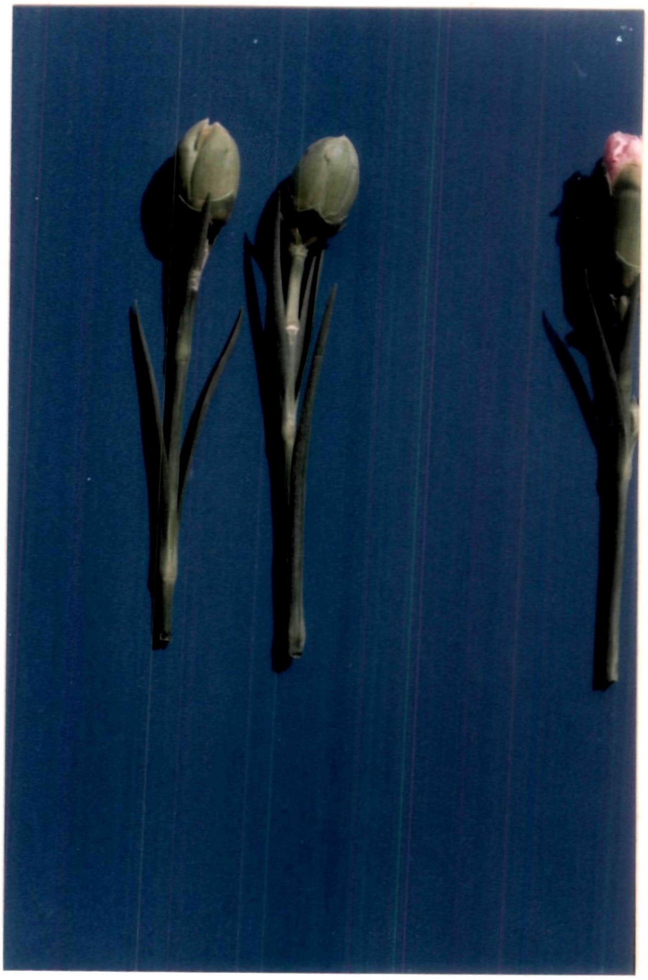
Stage IV = shoots with fully opened flower (14.55)

The number of eggs, nymphs and adults of *Tetranychus urticae* were recorded on leaves and flower buds at various stages of growth. Later, after harvest the flowers were sorted by the growers into different quality grades like good, medium and bad based on appearance of flowers.

The monetary loss was calculated based on the selling price for different grades of flowers. The good quality flowers fetched Rs.48/dozen followed by medium quality flowers, which were sold at 50% value i.e., @ Rs.25/dozen and the bad quality flowers were rejected.

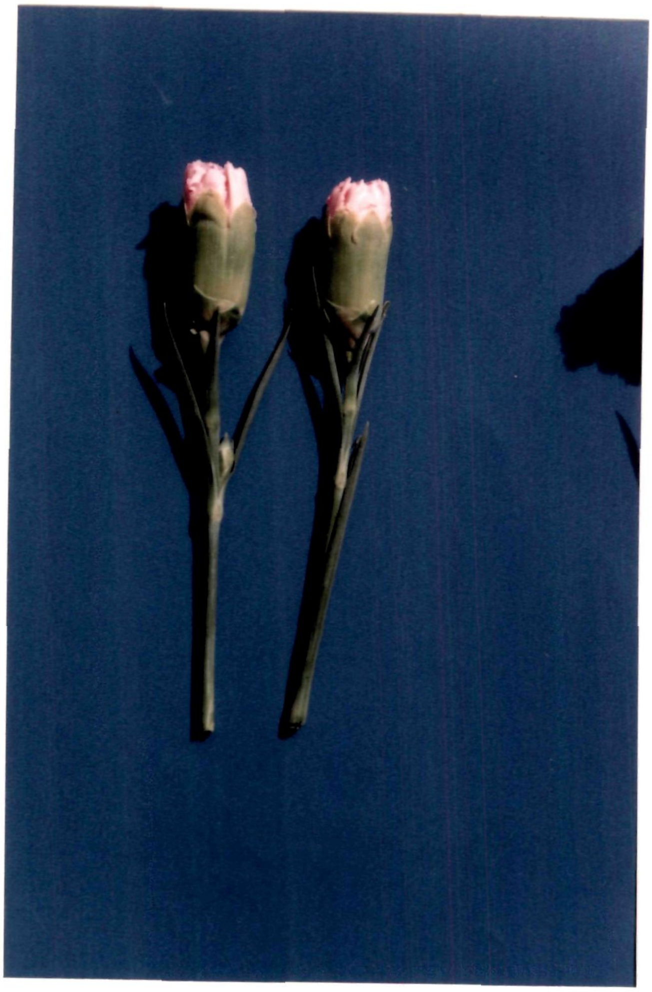


Stage –I

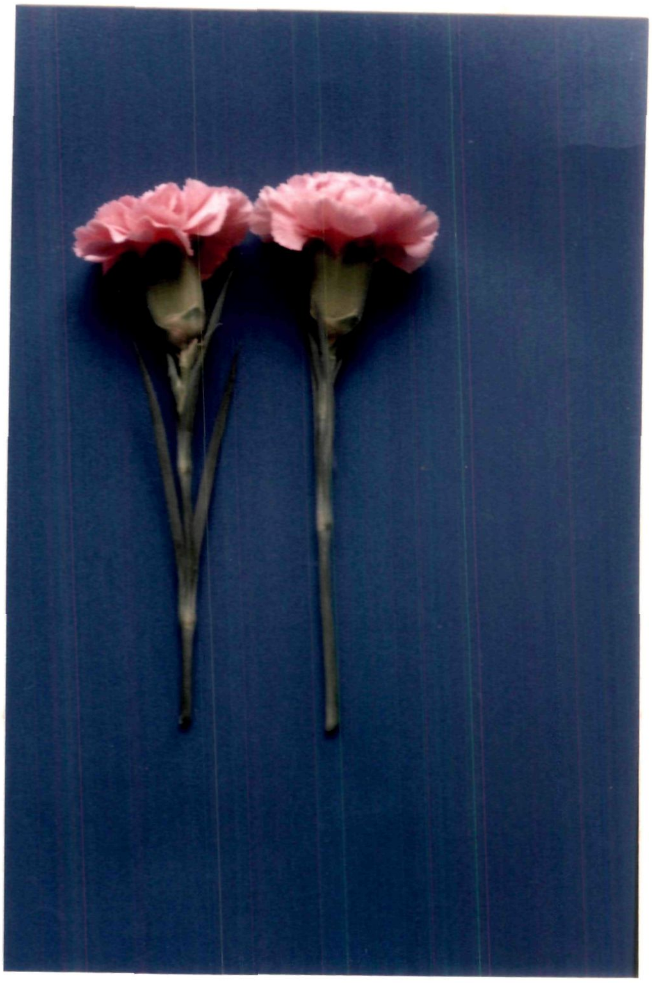


Stage –II

Flower bud at the growth stage I and II



Stage –III



Stage –IV

Flower bud at the stage III and IV

Table 2. The size (mm) of flower buds during different stages in different varieties of carnation.

Varieties	Flower bud stages			
	Stage I	Stage II	Stage III	Stage IV
Cabaret	11.85	16.33	17.52	15.20
Navajo	11.78	15.90	17.00	15.18
Rirandello	11.89	16.84	17.67	15.87
Desio	11.68	16.70	18.20	15.06
Feyenoord	11.55	18.81	20.40	19.59
Furlano	10.85	16.50	18.20	15.80
Kartina	7.80	12.75	13.00	11.20
Grafield	7.22	12.66	13.54	11.90
Grafitti	7.88	12.66	13.10	11.20
Average	10.27	15.46	16.51	14.55

Size - Diameter at calyx region

3.3 Management of *T.urticae* using phytoseiids:

3.3.1 Mass production of *Amblyseius longispinosus* :

The predator, *Amblyseius longispinosus* used in the study was mass produced in the glass house of Department of Entomology, U.A.S, GKVK. It includes the following two steps.

1. The development of *T. urticae* on French bean plants
2. Mass multiplication of predators

3.3.1.1 The development of *T. urticae* on French bean plants:

French bean plants, variety Burfi- stringless, was used since it is a variety resistant to leaf rust. The seeds were sown in earthen pots (22 cm diameter). The pot mixture was prepared with red soil and farm yard manure (FYM). Before filling, the pot mixture was fumigated using formalin one percent to kill the pathogens, which cause collar rot of beans. After one week the pots were filled with the mixture and French bean seeds were sown. In each pot two seedlings were retained, 12 days after sowing (DAS) when the seedlings had attained three compound leaf (nine leaflet) stage. They were infested with spider mites, which were initially collected from the field. Culturing of the spider mites was later continued on similar plants.

3.3.1.2 Mass production of *Amblyseius longispinosus*

The mass multiplication of the predator was carried out by following the model developed by Mallik, *et al.*, (1999).

3.3.1. 3 Management of spider mite using phytoseiids:

This study was carried out in the greenhouse of Rashmi farm of Indo-American hybrid seeds, India (Pvt.) Ltd, at Kengeri, Bangalore. The varieties selected for the study included Cabaret, Navajo, Rirandello, Feyenoord, Furlano, Desio, Grafield and Kartina. Plots measuring about 2 x 1 metre area were demarkated and a gap of about 1 metre was maintained between each variety. In each variety two plots were maintained, of these, in one plot the predators were released and the other plot was without predators. The plants had uniform infestation of *T.urticae*. Before laying out the experiment 20 leaves from each plot at different canopy levels were randomly collected, brought to the laboratory and observed under a stereobinocular microscope to record the number of egg, nymph and adult stages of *T.urticae*. The average number of mites per leaf was calculated. Total population of *T. urticae* in each experimental plot was determined considering the total number of leaves per plant, number of shoots per plant and total number plants in each plot (2 x 1 metre area). Based on the total population of spider mites in each plot the number of predators required for the release was calculated. In all the varieties the predators were released in the ratio of 1:20 predator to prey. Twenty leaves from each plot at different canopy levels were sampled before release of the predators and it was continued at weekly intervals for seven weeks after the release of the predators. Samples were collected in separate polythene covers brought to the laboratory to record number of egg, nymph and adult stages of both the prey and predator. The data collected was subjected to t- test.

EXPERIMENTAL RESULTS

IV RESULTS:

4.1 Distribution and sampling of *Tetranychus urticae* on carnation.

4.1.1. Distribution of eggs, nymphs and adult stages of *T. urticae* in different varieties of carnation.

The number of different stages of the mite was recorded from both surfaces of the leaf at three different canopy levels and also on the flower buds. All the three stages of the mite, *viz.*, eggs, nymphs and adults followed a similar pattern of distribution in all the varieties of carnation. The leaves of the top canopy harboured more number of eggs, nymphs and adults followed by middle and bottom canopy leaves. Within each leaf the upper surface had significantly higher number of eggs, nymphs and adults followed by lower surface of the leaf. If the whole plant is considered, upper surface of the top canopy leaves had the highest number of different stages of the mite and lower surface of the bottom canopy leaves had the lowest number of eggs, nymphs and adults. The relationship between number of different stages of the mite and their variance was analyzed. Coefficient of variation for the population of different stages of *T.urticae* on upper and lower surfaces of top, middle and bottom canopy leaves was computed. The number of different stages on each leaf surface was correlated with the total population of the respective stage on the plant. The population of eggs on the upper leaf surface of the top canopy leaves in most of the varieties had high correlation value and low coefficient of variation. The nymphs and adults followed a similar trend of distribution as that of eggs. Whereas leaf surfaces of middle and bottom canopy leaves had low correlation for most of the varieties for all the stages of spider mites (Fig .1,2,3,4,5 and 6).

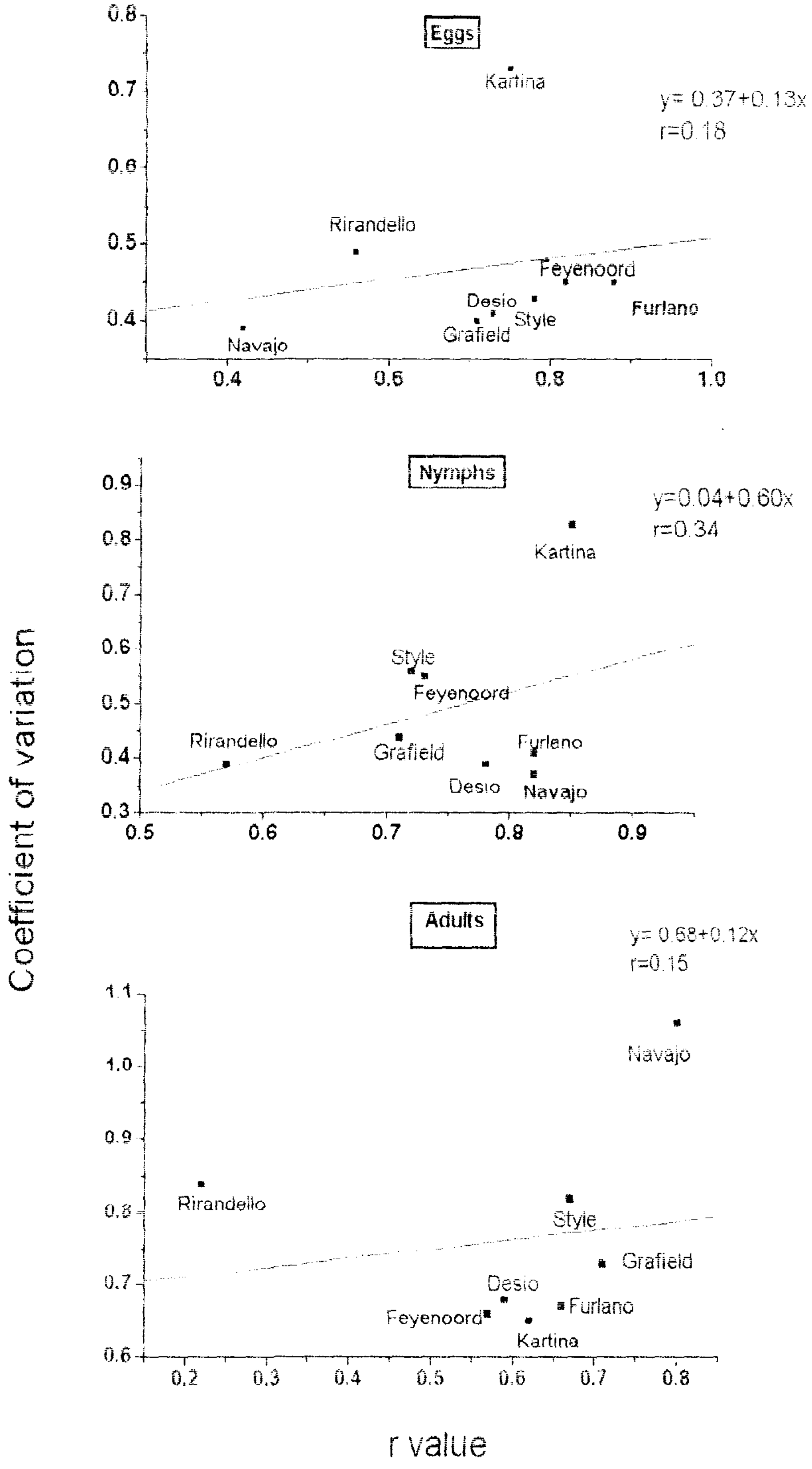


Fig 1. Relationship betwwen the number of eggs, nymphs and adults on upper leaf surface of the top canopy and correlation between this number and the population mean.

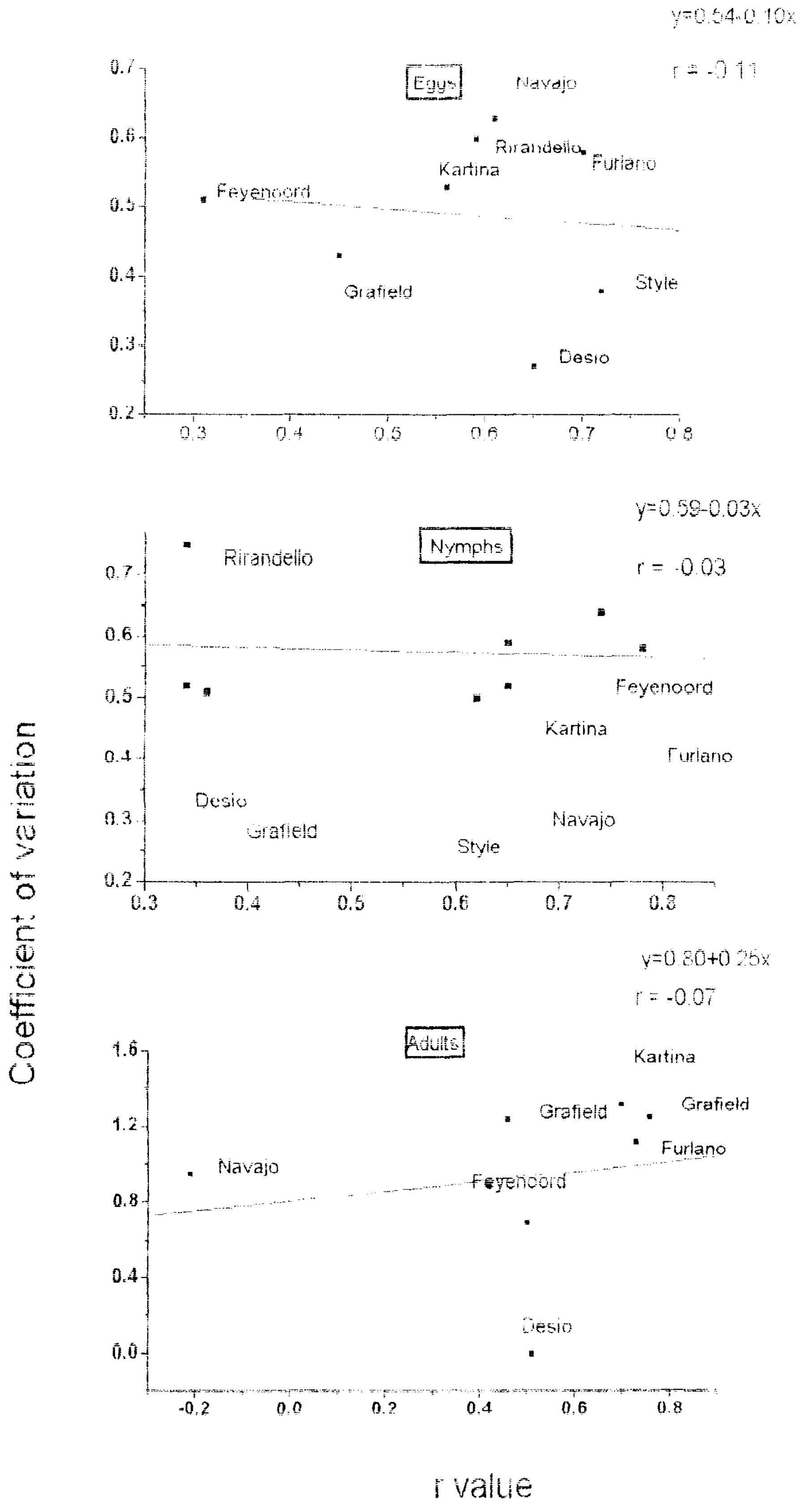


Fig 2. Relationship between CV of the number of eggs, nymphs and adults on lower leaf surface of the top vanopy and correlation between this number and the population mean.

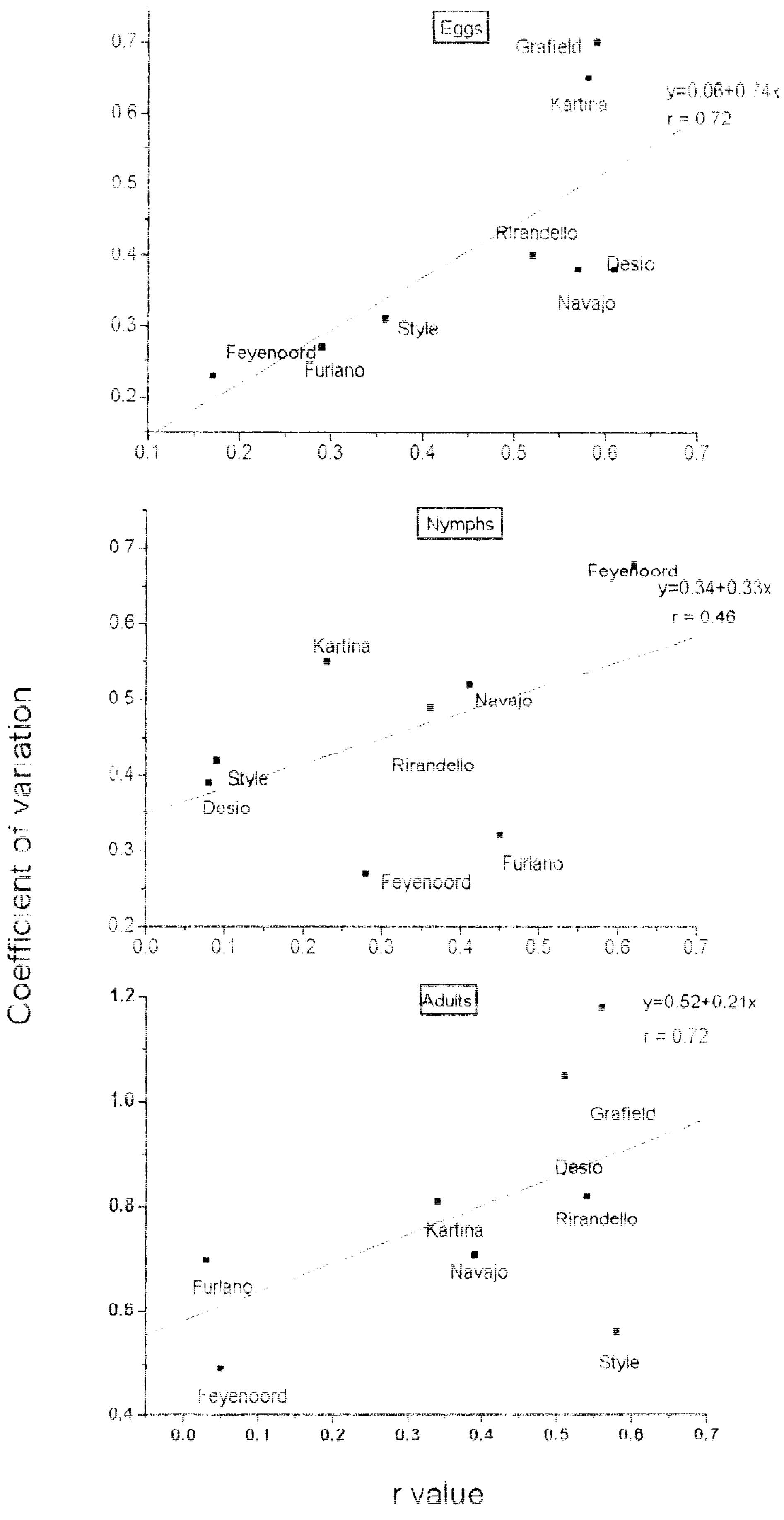


Fig 3. Relationship between CV of the number of eggs, nymphs and adults on upper leaf surface of the middle canopy and correlation between this number and the population mean.

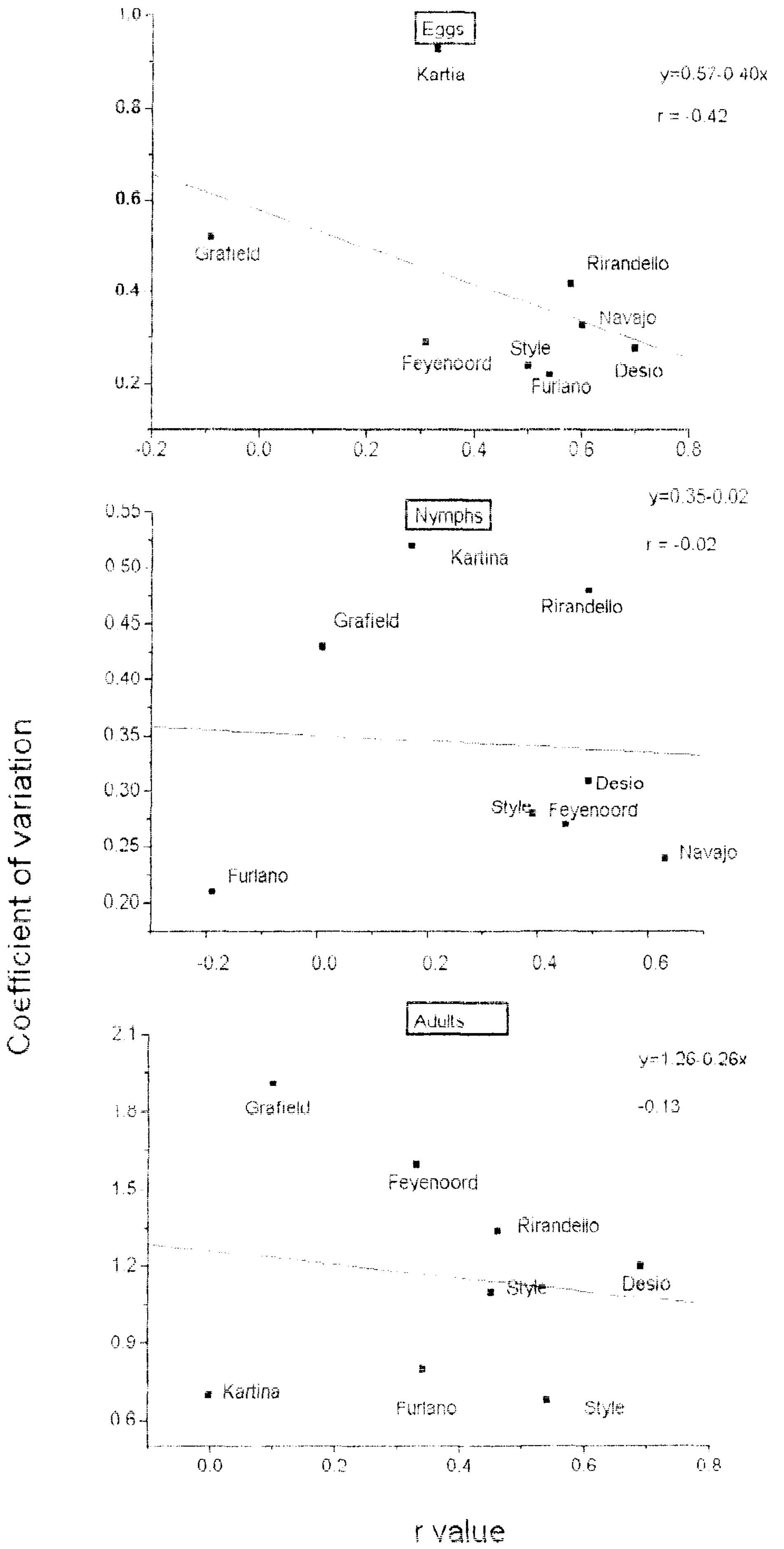


Fig 4. Relationship between CV of the number of eggs, nymphs and adults on lower leaf surface of the middle canopy and correlation between this number and the population mean.

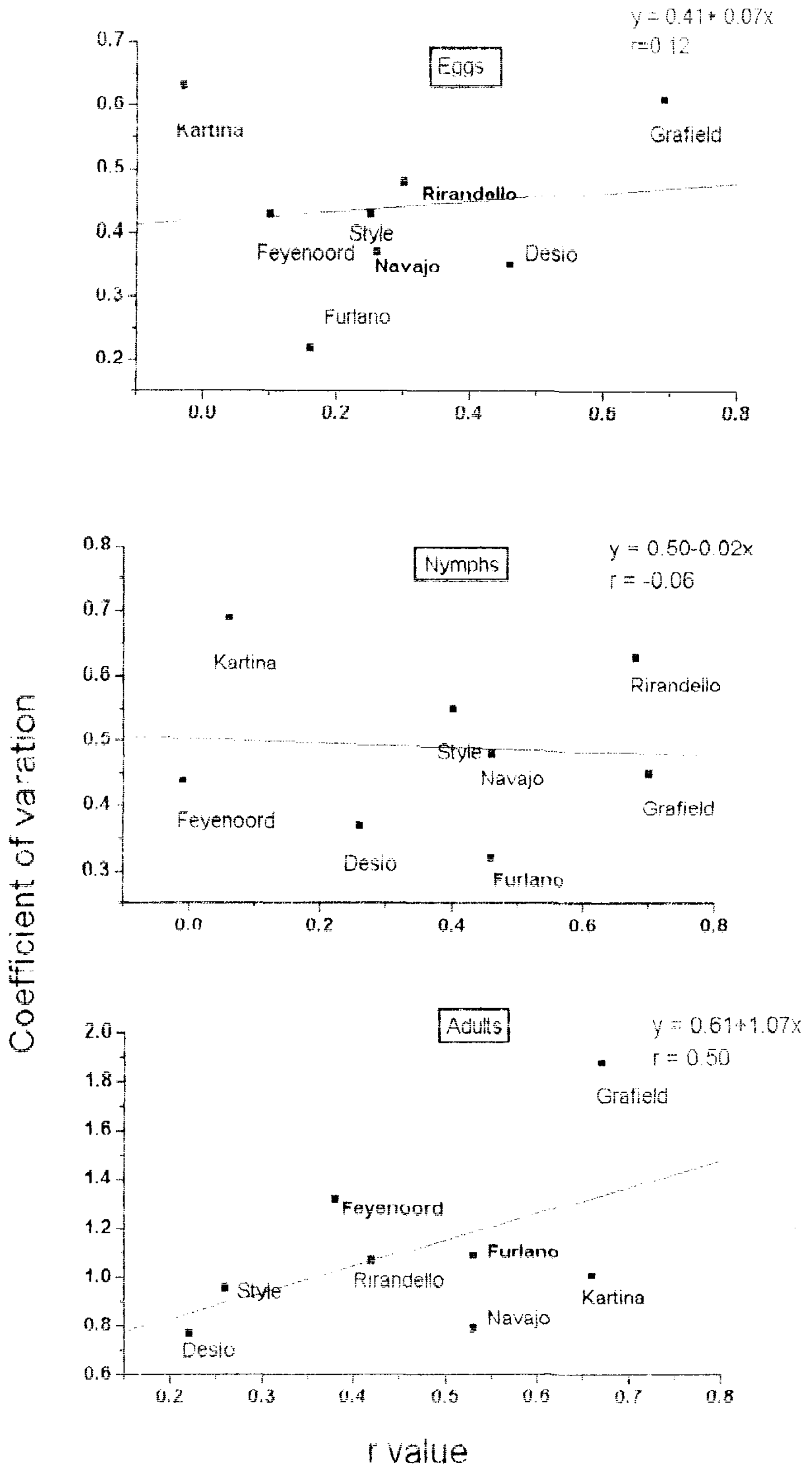


Fig 5. Relationship betwwen the number of eggs, nymphs and adults on upper leaf surface of the bottom canopy and correlation between this number and the population mean.

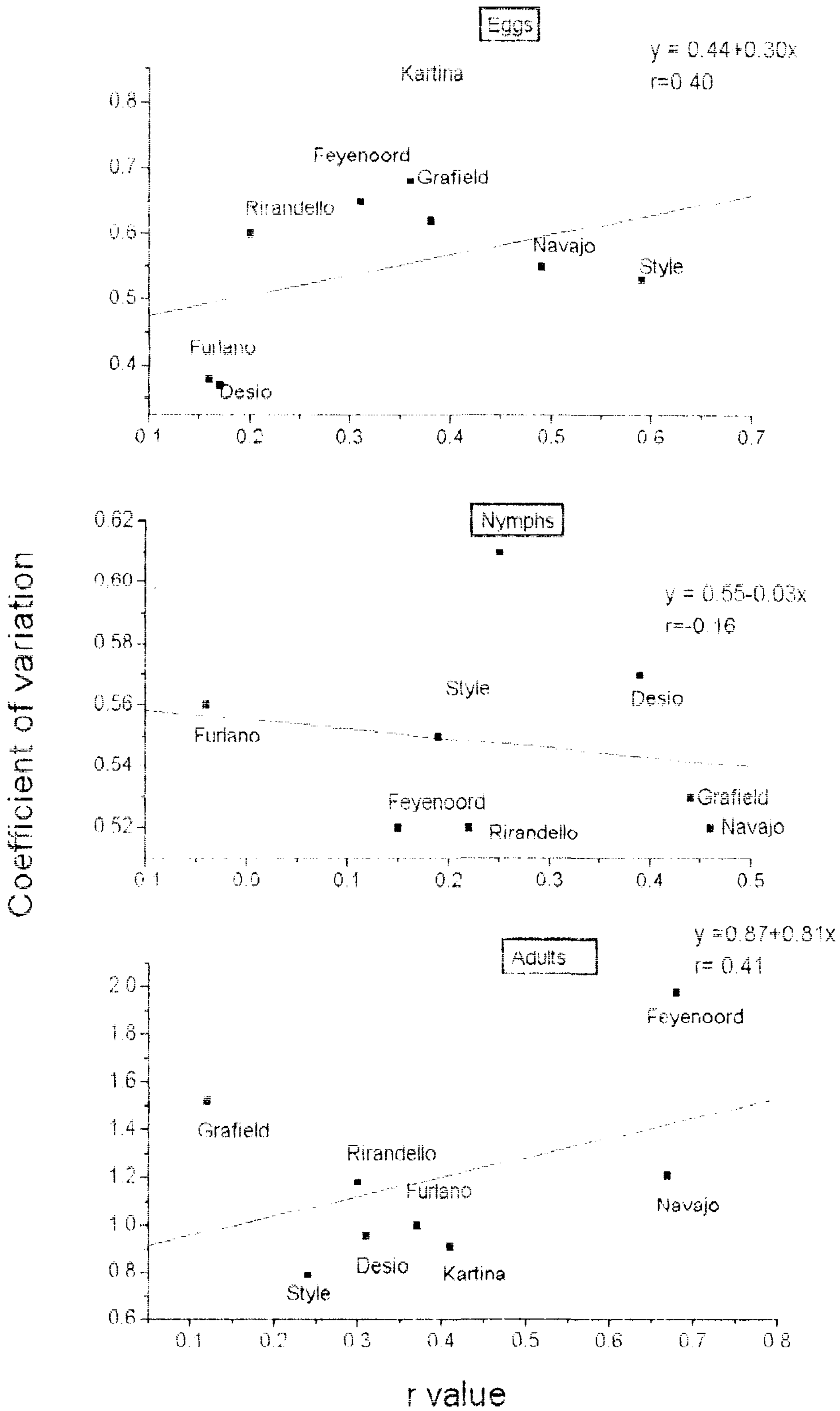


Fig 6. Relationship betwwen the number of eggs, nymphs and adults on lower leaf surface of the bottom canopy and correlation between this number and the population mean.

4.1.1.1 Distribution on varieties Rirandello, Grafield and Kartina:

In the variety Rirandello, the mean number of eggs on the upper surface of leaves of bottom, middle and top canopy leaves was 46.66, 61.3 and 77.48, respectively whereas on the lower surface it was 45.55, 52.48 and 62.86, respectively. The mean number of nymphs on the upper surface of leaves of the bottom, middle and top canopy leaves was 60.00, 89.11 and 105.26, respectively while on the lower surface 52.22, 72.28 and 74.56 mites, respectively were recorded. The mean number of adults on the upper surface of leaves of the bottom, middle and top canopy leaves was 20.00, 34.65 and 35.06, respectively whereas on the lower surface 17.77, 18.81 and 32.16 mites, respectively were recorded. The average number of egg, nymph and adult stages of the spider mites on a flower was 6.75, 7.62 and 3.12, respectively (Table 3). The population of mites on varieties Grafield and Kartina had distribution similar to that on variety Rirandello (Table 4 & 5).

4.1.1.2 Distribution on varieties Feyenoord and style:

In the variety Feyenoord, the mean number of eggs on the upper surface of leaves of bottom, middle and top canopy was 63.08, 79.17 and 95.24, respectively, whereas on the lower surface 54.90, 77.08 and 63.49 mites, respectively were recorded. The mean number of nymphs on the upper surface of leaves of the bottom, middle and top canopy was 75.93, 90.63 and 107.94, respectively while the lower surface harboured 68.92, 87.50 and 77.78 mites, respectively. The mean number of adults on the upper surface of leaves of bottom, middle and top canopy was 18.69, 47.92 and 57.14, respectively, whereas on the lower surface 14.01, 16.67 and 33.33 mites, respectively were recorded. The average number of eggs, nymphs and adults of the spider mites on a flower was 6.37,

Table 3. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Rirandello. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	46.66	45.55	92.22	61.39	52.48	113.86	77.48	62.86	140.35	6.75
S.D	22.68	27.43	41.58	24.80	22.51	39.54	38.27	38.27	60.44	1.92
VARIANCE	514.61	752.43	1729.69	615.01	506.66	1563.31	1464.68	1464.68	3653.84	3.69
					Nymphs					
MEAN	60.00	52.22	112.22	89.11	72.28	161.39	105.26	74.56	179.82	7.62
S.D	38.21	27.24	56.52	43.81	34.76	66.85	41.78	56.50	78.95	1.73
VARIANCE	1460.68	742.04	3195.58	1919.32	1208.34	4469.12	1745.92	3192.61	6234.48	2.99
					Adults					
MEAN	20.00	17.77	37.77	34.65	18.81	53.47	35.06	32.16	67.22	3.12
S.D	21.50	21.14	29.81	28.64	25.27	43.62	29.52	23.04	30.77	0.71
VARIANCE	462.63	447.04	888.88	820.35	638.74	1902.81	871.71	530.97	947.01	0.51

U.S. = Upper Surface L.S. = Lower Surface T = Total

Table 4. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Grafield. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
Eggs										
MEAN	53.65	39.02	140.24	69.04	41.66	110.71	74.02	55.84	129.87	5.37
S.D	33.19	24.26	55.88	48.79	21.67	43.88	15.25	24.24	29.91	0.81
VARIANCE	1102.10	588.62	3123.14	2380.95	469.92	1925.94	232.57	587.65	852.18	0.66
Nymphs										
MEAN	71.95	68.29	140.24	78.57	71.42	150.00	127.27	71.42	198.70	7.87
S.D	33.05	36.77	55.88	54.12	30.89	65.59	56.46	36.61	79.17	1.53
VARIANCE	1094.27	1352.57	3123.14	2929.94	954.76	4302.42	3188.60	1340.42	6268.91	2.34
Adults										
MEAN	15.85	10.97	26.82	19.04	8.33	27.38	46.75	23.37	70.12	3.87
S.D	29.89	16.73	32.53	22.65	15.97	25.93	34.33	29.07	46.23	0.82
VARIANCE	893.89	280.22	1058.26	513.18	255.10	672.81	1178.86	845.08	2137.57	0.68

U.S. = Upper Surface L.S. = Lower Surface T = Total

Table 5. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Kartina. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	44.82	28.73	73.56	45.65	31.52	77.17	83.61	68.25	151.87	4.87
S.D	28.37	19.55	37.73	29.84	29.48	50.60	61.12	36.72	80.97	0.68
VARIANCE	805.22	382.44	1424.09	890.45	869.31	2560.69	3736.67	1348.75	6556.80	0.47
					Nymphs					
MEAN	54.02	40.22	94.25	54.34	47.82	102.17	85.32	81.19	167.23	7.12
S.D	37.49	24.59	44.06	30.33	25.03	45.21	71.33	48.77	105.57	1.69
VARIANCE	1406.01	604.96	1941.43	920.30	626.80	2044.57	5088.49	2378.71	11145.64	2.87
					Adults					
MEAN	25.28	22.98	48.27	27.17	25.00	52.17	49.48	27.30	76.79	2.37
S.D	25.72	21.09	33.27	22.16	17.66	29.42	32.23	36.05	55.22	1.14
VARIANCE	661.98	445.02	1107.00	491.24	312.15	865.58	1039.15	1299.71	3050.03	1.31

U.S. = Upper Surface L.S. = Lower Surface T = Total

8.12 and 2.87, respectively (Table 4). The variety Style, had distribution similar to mites on variety Feyenoord (Table 7).

4.1.1.3 Distribution on variety Navajo:

In this variety the average number of eggs on the upper surface of leaves of bottom, middle and top canopy was 59.14, 64.65 and 74.56, respectively whereas on the lower surface 48.39, 52.53 and 64.33 eggs, respectively were recorded. The average number of nymphs on the upper surface of leaves of bottom, middle and top canopy was 58.06, 96.97 and 159.36, respectively while on the lower surface 58.06, 68.69 and 112.57 nymphs, respectively were recorded. The average number of adults on the upper surface of leaves of the bottom, middle and top canopy was 33.33, 36.36 and 42.40, respectively whereas on the lower surface 22.58, 29.29 and 35.09 adults, respectively were recorded. The average number of egg, nymph and adult stages of the spider mites on the flower was 9.25, 13.75 and 4.00, respectively (Table 8).

4.1.1.4 Distribution on variety Desio:

The mean number of eggs on the upper surface of leaves of the bottom, middle and top canopy was 80.00, 103.17 and 103.22, respectively whereas on the lower surface 71.42, 101.85 and 103.22 mites, respectively were recorded. The mean number of nymphs on the upper surface of leaves of the bottom, middle and top canopy was 72.85, 119.05 and 150.00, respectively whereas on the lower surface it was 61.42, 97.88 and 98.38 mites, respectively. The mean number of adults on the upper surface of leaves of the bottom, middle and top canopy leaves was 31.42, 35.71 and 62.90, respectively whereas on the lower surface 28.57, 41.01 and 43.54 mites, respectively were recorded.

Table 6. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Feyenoord. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	63.08	54.90	117.99	79.17	77.08	156.25	95.24	63.49	158.73	6.37
S.D	27.43	35.77	44.50	18.63	19.24	32.06	60.06	32.57	71.36	0.75
VARIANCE	752.76	1279.99	1981.03	347.22	370.07	1027.96	3606.90	1060.85	5092.10	0.57
					Nymphs					
MEAN	75.93	68.92	89.95	90.63	87.50	156.25	107.94	77.78	141.27	8.12
S.D	33.79	35.93	45.65	24.63	23.99	32.06	60.41	49.90	66.33	1.48
VARIANCE	1142.07	1291.48	2084.47	606.50	575.66	1027.96	3649.33	2490.35	4399.89	2.19
					Adults					
MEAN	18.69	14.01	32.71	47.92	16.67	64.58	57.14	23.33	90.48	2.87
S.D	24.68	27.74	45.10	23.51	26.70	30.90	37.98	29.98	53.79	0.87
VARIANCE	609.10	770.00	2034.19	552.81	712.72	954.86	1442.76	899.07	2893.48	0.76

U.S. = Upper Surface L.S. = Lower Surface T = Total

Table 7. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Style. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	67.66	53.89	121.55	79.00	70.34	149.35	79.32	73.65	152.97	16.87
S.D	29.27	29.08	42.06	24.60	20.9*2	32.10	36.30	37.22	54.68	1.44
VARIANCE	856.90	845.83	1777.49	605.36	437.68	1030.71	1317.81	1385.39	2990.40	2.09
					Nymphs					
MEAN	60.77	60.77	121.55	86.58	76.83	163.41	126.06	73.65	199.78	18.37
S.D	33.50	33.50	46.53	36.49	21.61	42.98	70.88	37.22	93.04	1.92
VARIANCE	1122.70	1122.70	2165.11	1331.54	467.27	1848.13	5024.14	1385.39	8656.55	3.71
					Adults					
MEAN	28.66	19.49	48.16	41.12	23.18	64.93	42.49	18.41	60.91	7.50
S.D	27.71	18.64	31.48	23.18	26.18	39.72	35.00	23.07	42.39	1.83
VARIANCE	768.30	347.46	991.18	537.55	685.49	1578.12	1224.88	530.08	1797.20	3.36

U.S. = Upper Surface L.S. = Lower Surface T = Total

Table 8. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Navajo. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
Eggs										
MEAN	59.14	48.39	107.52	64.65	52.53	117.17	74.56	64.33	138.87	9.25
S.D	21.93	26.91	41.27	25.04	17.83	35.05	29.20	40.91	50.09	1.38
VARIANCE	480.74	724.15	1703.87	627.22	317.91	122.86	852.71	1673.93	2508.64	1.90
Nymphs										
MEAN	58.06	58.06	116.13	96.97	68.69	165.66	159.36	112.57	271.93	13.75
S.D	28.00	30.49	52.86	50.60	16.58	56.61	59.60	59.45	107.79	3.67
VARIANCE	783.78	929.83	2794.36	2560.43	274.95	3205.83	3552.6	3534.60	11618.51	13.52
Adults										
MEAN	33.33	22.58	55.91	36.36	29.29	65.66	42.54	35.90	77.49	4.00
S.D	26.55	27.45	42.67	25.89	20.18	32.69	44.97	33.67	52.20	0.99
VARIANCE	704.68	753.36	1820.72	670.18	407.05	1068.63	2022.66	1133.95	2724.64	00.98

U.S. = Upper Surface L.S. = Lower Surface T = Total

The average number of egg, nymph and adult stages of the spider mites on a flower was 6.25, 7.25 and 3.37, respectively (Table 9).

4.1.1.5 Distribution on variety Furlano:

The mean number of eggs recorded on the upper surface of leaves of the bottom, middle and top canopy was 53.53, 71.15 and 111.54, respectively whereas on the lower surface it was 54.54, 69.23, and 76.92 mites, respectively. The mean number of nymphs on the upper surface of the bottom, middle and top canopy leaves was 62.62, 100.96 and 200.00, respectively whereas on the lower surface 44.44, 91.34 and 125.00 mites, respectively were recorded. The mean number of adults on the upper surface of the bottom, middle and top canopy leaves was 22.22, 43.26 and 63.46, respectively whereas on the lower surface 21.21, 37.50 and 38.46 mites, respectively were recorded. The average number of egg, nymph and adult stages of the spider mites on a flower was 6.00, 7.87 and 3.87, respectively (Table 10).

4.2.1 Loss caused due to mite infestation on different varieties of carnation.

The study on the estimation of loss caused due to mite infestation was carried out by following two methods.

1. Grading harvested flowers into different quality grades
2. Studying the flower stage related loss.

The results obtained by the above two methods are presented below.

Table 9. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Desio. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	80.00	71.452	151.42	103.17	101.85	205.03	103.22	103.22	206.45	6.25
S.D	28.72	27.02	46.344	40.17	28.82	58.13	32.42	28.85	49.53	0.51
VARIANCE	824.91	730.39	2156.82	1613.38	83.06	3379.63	1051.53	832.46	2453.58	0.23
					Nymphs					
MEAN	72.85	61.42	134.28	119.05	97.88	216.93	150.00	98.38	248.38	7.25
S.D	26.98	35.02	54.91	46.62	31.07	59.83	58.52	51.77	79.77	1.41
VARIANCE	728.24	1226.63	3016.11	2173.28	965.08	3580.38	3425.70	2680.87	6363.98	1.98
					Adults					
MEAN	31.42	28.57	60.00	35.71	41.01	76.72	62.90	43.54	106.45	3.37
S.D	24.34	22.70	38.10	37.68	51.84	76.24	42.48	30.10	60.21	0.98
VARIANCE	592.91	515.57	1452.20	1420.00	2687.13	5812.59	1804.59	906.40	3625.60	0.97

U.S. = Upper Surface   L.S. = Lower Surface   T = Total

Table 10. Distribution of eggs, nymphs and adults of *Tetranychus urticae* on carnation cv Furlano. (Number per 100 sq cm leaf area)

	BOTTOM CANOPY			MIDDLE CANOPY			TOP CANOPY			FLOWER BUD
	U.S	L.S	T	U.S	L.S	T	U.S	L.S	T	
					Eggs					
MEAN	53.53	54.54	108.08	71.15	69.23	140.38	111.54	76.92	188.46	6.00
S.D	11.86	20.83	26.44	19.82	15.78	27.26	64.72	44.99	95.76	0.59
VARIANCE	140.69	433.89	699.17	393.17	249.14	743.53	4188.73	2024.29	9171.59	0.35
					Nymphs					
MEAN	62.62	44.44	107.07	100.96	91.34	192.30	200.00	125.00	325.00	7.87
S.D	20.62	25.04	33.48	32.94	19.60	35.29	83.34	73.69	134.09	1.53
VARIANCE	425.30	627.21	1121.26	1085.13	384.42	1245.71	6944.88	5430.55	17981.16	2.34
					Eggs					
MEAN	22.22	21.21	43.43	43.26	37.50	80.76	63.46	38.46	101.92	3.87
S.D	24.43	21.21	36.06	30.48	30.22	37.74	43.72	43.23	68.66	0.82
VARIANCE	597.14	450.00	1300.61	921.42	913.85	1424.79	1911.40	1868.58	4714.26	0.68

U.S. = Upper Surface L.S. = Lower Surface T = Total

4.2.1.1 Population of mites on harvested flowers of different quality grades in different varieties of carnation (Table 11).

Bad quality flowers had more number of spider mites per flower followed by medium and good quality flowers in the different varieties of carnation included for the study.

cabaret:

The number of all stages of *Tetranychus urticae* on good, medium and bad quality flowers was 12.32, 25.65 and 46.92 per flower, respectively.

Navajo:

Good, medium and bad quality flowers had 10.12, 27.75 and 42.60 spider mites per flower, respectively.

Feyenoord:

The population of all stages of the spider mite recorded on good, medium and bad quality flowers was 9.25, 21.37 and 36.05 per flower, respectively .

Rirandello:

On good, medium and bad quality flowers the population of *T. urticae* was 9.65, 21.40 and 34.52 per flower, respectively.

Graffitti:

The population of the spider mite on good, medium and bad quality flowers was 7.22, 20.00 and 34.00 per flower, respectively.

Table 11. Population of *Tetranychus urticae* on harvested flowers of different quality grades in different varieties of carnation.

Variety	Average no. of mites (all stages) per flower of different quality grades		
	Good	Medium	Bad
Cabaret	12.32	25.65	46.92
Navajo	10.12	27.75	42.60
Feyenoord	9.25	21.37	36.05
Rirandello	9.65	21.40	34.52
Grafitti	7.22	20.00	34.00
Furlano	10.40	21.87	33.95
Kartina	6.95	18.25	30.90
Grafield	7.35	18.15	29.85
Desio	10.00	17.50	23.00
Average	9.25	21.33	34.64

Furlano:

The number of spider mites on good, medium and bad quality flowers was 10.40, 21.87 and 33.95 per flower, respectively.

Kartina :

The good, medium and bad quality flowers were harbouring 6.95, 18.25 and 30.90 spider mites per flower, respectively (Table 9).

Grafield:

The population of spider mites on good, medium and bad quality flowers was 7.35, 18.15 and 29.85 per flower, respectively.

Desio :

The number of spider mites on good, medium and bad quality flowers was 10.00, 17.50 and 23.00 per flower, respectively.

4.2.1.2 Estimation of monetary loss due to mite infestation in different varieties of carnation (Table 12).

Kartina:

The percentage of good, medium and bad quality flowers was 60.32, 18.86 and 20.75 respectively. The expected income was Rs. 212.00 per 53 flowers whereas the actual income was Rs. 148.81. The calculated per cent monetary loss was 29.80, which was maximum among the different varieties of carnation.

Feyenoord:

The percentage of good, medium and bad quality flowers was 61.26, 19.81 and 18.91 respectively. The expected and the actual income were Rs. 444.00 and Rs. 317.82, respectively per 111 flowers. The per cent monetary loss was 28.41.

Grafield:

The per cent of good, medium and bad quality flowers was 62.24, 19.38 and 18.36, respectively. The expected and the actual income were Rs. 392.00 and Rs. 283.56, respectively per 98 flowers. The per cent monetary loss was 27.60.

Cabaret:

The percentage of good, medium and bad quality flowers was 64.38, 17.80 and 17.80, respectively. The expected income was Rs. 584.00 per 146 flowers and the actual income was Rs. 430.15. The calculated per cent monetary loss was 26.34.

Navajo:

The percentage of good, medium and bad quality flowers was 69.50, 14.89 and 15.60, respectively. The expected income was Rs. 564.00 per 141 flowers whereas the actual income was Rs. 435.73. The calculated per cent monetary loss was 26.65.

Desio:

In this variety the percentage of good, medium and bad quality flowers was 68.04, 15.46 and 16.49, respectively. The expected and the actual income were Rs.

Table 12. Effect of mite infestation on quality of flowers and resultant monetary loss in different varieties of carnation.

Varieties	Flower grades			Expected Income (Rs)	Actual Income (Rs)	Percent loss
	Good	Medium	Bad			
Kartina (n=53)	32 (60.32)	10 (18.86)	11 (20.75)	212.00	148.81	29.80
Feyenoord (n=111)	68 (61.26)	22 (19.81)	21 (18.91)	444.00	317.22	28.41
Grafield (n=98)	61 (62.24)	19 (19.38)	18 (18.36)	392.00	283.56	27.60
Cabaret (n=146)	94 (64.38)	26 (17.80)	26 (17.80)	584.00	430.15	26.34
Navajo (n=141)	98 (69.50)	21 (14.89)	22 (15.60)	564.00	435.73	22.74
Desio (n=97)	66 (68.04)	15 (15.46)	16 (16.49)	388	295.23	23.90
Grafitti (n=26)	19 (73.07)	2 (7.69)	5 (19.23)	104.00	80.16	22.92
Rirandello (n=115)	82 (71.30)	16 (13.90)	17 (14.28)	460.00	365.31	20.58
Furlano (n=105)	73 (69.52)	17 (16.19)	15 (14.28)	420.00	327.39	22.05

(Values in the parentheses indicates the percentages)

***Income calculated as Rs. 48.00 per dozen of good quality flowers and Rs. 24.00 per dozen of medium quality flowers.**

***Expected income was computed by considering the price of good quality flowers.**

388.00 and Rs. 295.23, respectively per 97 flowers. The calculated per cent monetary loss was 23.90.

Grafitti:

In this variety the percentage of good, medium and bad quality flowers was 73.07, 7.69 and 19.23, respectively. The expected and the actual income were Rs. 104 and Rs.80.16, respectively per 26 flowers. The calculated per cent monetary loss was 22.92.

Rirandello:

The percentage of good, medium and bad quality flowers in this variety was 71.30, 13.90 and 14.78, respectively. The expected income was Rs. 460.00 per 115 flowers whereas the actual income was Rs. 365.31. The calculated per cent monetary loss was 20.58.

Furlano:

The percentage of good, medium and bad quality flowers was 69.52, 16.19 and 14.28, respectively. The expected income was Rs. 420.00 per 105 flowers whereas the actual income was Rs. 327.29. The calculated per cent monetary loss was 22.05.

4.2.2.1 Stage related losses: (Table 13. Fig. 7)

At stage I if the population of the adults on leaf and flower bud was 2.01 and 1.5, respectively it was observed that the flower harvested from such shoots was not affected whereas if the population of adults was 2.66 and 2.15, respectively it was observed that the flower harvested from such shoots was moderately affected and the quality of the flower at the tine of harvest was medium. But an average of 3.16 and 3.12 adults on leaf and flower bud, respectively severely affected the growth of the flower, and the quality of the flower at the time of harvest was bad.

At stage I if the population of nymphs on leaf and flower bud was 5.68 and 3.87, respectively it was observed that the quality of the flower harvested from such shoots was not affected whereas the population of about 7.40 and 5.15 mites, respectively moderately affected the growth of the flower and the quality of the flower was medium at the time of harvest. But if the population on leaf and flower bud was 10.50 and 8.75, respectively it was found that the flower harvested from such shoots was severely affected and the quality of the flower was bad.

At stage I if the population of eggs on leaf and flower bud was 4.46 and 1.75, respectively it was found that the flower harvested from such shoots was not affected and the quality of the flower was good whereas if the population of eggs was 5.26 and 2.32, respectively the flower harvested from such shoots was moderately affected and the quality of the flower was medium. But if the population of eggs on leaf and flower bud was 6.91 and 3.75, respectively it was observed that the flower harvested from such shoots was severely affected and the quality of the flower was bad.

At stage II when the population of the adults on leaf and flower bud was 2.14 and 2.2, respectively it was observed that the flower harvested from such shoots was not affected, and the quality of the flower was good, whereas if the population of adults was 2.74 and 3.6, respectively it was observed that the growth of the flower was moderately affected, and the quality of the flower at the time of harvest was medium. But an average of 3.44 and 4.70 adults on leaf and flower bud, respectively severely affected the growth of the flower and the quality of the flower was bad at the time of harvest.

At stage II if the population of nymphs on leaf and flower bud was 6.25 and 5.27, respectively it was observed that the quality of the flower harvested from such shoots was not affected whereas the population of about 7.62 and 7.2 mites, respectively moderately affected the flower, and the quality of the flower at the time of harvest was medium. But if the population on leaf and flower bud was 10.85 and 11.65, respectively it was found that the flower harvested from such shoots was severely affected and the quality of the flower was bad.

At stage II if the population of eggs on leaf and flower bud was 4.48 and 2.2, respectively it was found that the quality of the flower harvested from such shoots was not affected, whereas if the population of eggs was 5.55 and 3.32, respectively the flower harvested from such shoots was moderately affected and the quality of the flower was medium. And if the population of eggs on leaf and flower bud was 7.18 and 5.27, respectively it was observed that the flower harvested from such shoots was severely affected and the quality of the flower was bad.

At stage III if the population of the adults on leaf and flower bud was 2.49 and 3.20, respectively it was observed that the flower harvested from such shoots was not affected and the quality of the flower was good, whereas if the population of adults was 3.01 and 4.70, respectively it was observed that the quality of the flower was moderately affected and the flower was of medium quality at the tine of harvest. But an average of 4.84 and 5.65 adults on leaf and flower bud severely affected the quality of the flower, and the quality of the flower at the time of harvest was bad.

At stage III, if the population of nymphs on leaf and flower bud was 6.90 and 9.02, respectively it was observed that the quality of the flower harvested from such shoots was not affected, whereas the population of about 8.05 and 12.50 mites, respectively moderately affected the flower growth and the quality of the flower at the time of harvest was medium. But if the population of nymphs on leaf and flower bud was 10.13 and 17.15, respectively it was found that the flower harvested from such shoots was severely affected, and the quality of the flower was bad.

At stage III if the population of eggs on leaf and flower bud was 5.04 and 4.62, respectively it was found that the flower harvested from such shoots was not affected, whereas if the population of eggs was 6.03 and 5.27, respectively the quality of the flower harvested from such shoots was moderately affected, and the quality of the flower was medium. And if the population of eggs on leaf and flower bud was 7.37 and 7.32, respectively it was observed that the quality of the flower harvested from such shoots was severely affected, and the quality of the flower was bad.

At stage IV if the population of the adults on leaf and flower bud was 2.00 and 3.40, respectively it was observed that the flower harvested from such shoots was not affected, whereas if the population of adults was 2.46 and 5.75, respectively it was observed that the quality of the flower was moderately affected, and the quality of the flower at the time of harvest was medium. But an average of 3.45 and 7.95 adults on leaf and flower bud, respectively severely affected the quality of the flower, and the quality at the time of harvest was bad.

At stage IV if the population of nymphs on leaf and flower bud was 5.36 and 9.52, respectively it was observed that the quality of the flower harvested from such shoots was not affected, whereas the population of about 6.41 and 13.45 mites, respectively moderately affected the quality of the flower and the quality of the flower was medium at

Table 13. Influence of population of *T.urticae* during different stages of the shoot on the quality of the harvested flowers.

Fllower quality	No. of mites (all stages) / leaf				No. of mites (all stages) / flower bud			
	Eggs	Nymphs	Adults	Total	Eggs	Nymphs	Adults	Total
Stage I								
Good	4.46	5.68	2.01	12.15	1.75	3.87	1.50	7.12
Medium	5.26	7.40	2.66	15.32	2.32	5.15	2.15	9.62
Bad	6.91	10.50	3.16	20.57	3.75	8.75	3.12	15.62
Stage II								
Good	4.48	6.25	2.14	12.87	2.20	5.27	2.20	9.67
Medium	5.55	7.62	2.74	15.91	3.32	7.20	3.60	14.12
Bad	7.18	10.85	3.44	21.47	5.27	11.65	4.70	21.62
Stage III								
Good	5.04	6.90	2.49	14.43	4.62	9.02	3.20	16.54
Medium	6.03	8.05	3.01	17.09	5.27	12.50	4.70	22.47
Bad	7.37	10.13	4.84	22.34	7.32	17.15	5.65	30.12
Stage IV								
Good	4.30	5.36	2.00	11.66	5.45	9.52	3.40	18.37
Medium	5.51	6.41	2.46	14.38	7.00	13.45	5.75	26.20
Bad	7.03	10.93	3.45	21.41	9.52	20.45	7.95	37.92

Stage I – Shoots with 10.27 mm bud

Stage II – Shoots with 15.46 mm bud

Stage III – Shoots with 16.51 mm bud

Stage IV – Shoots with 14.45 mm bud

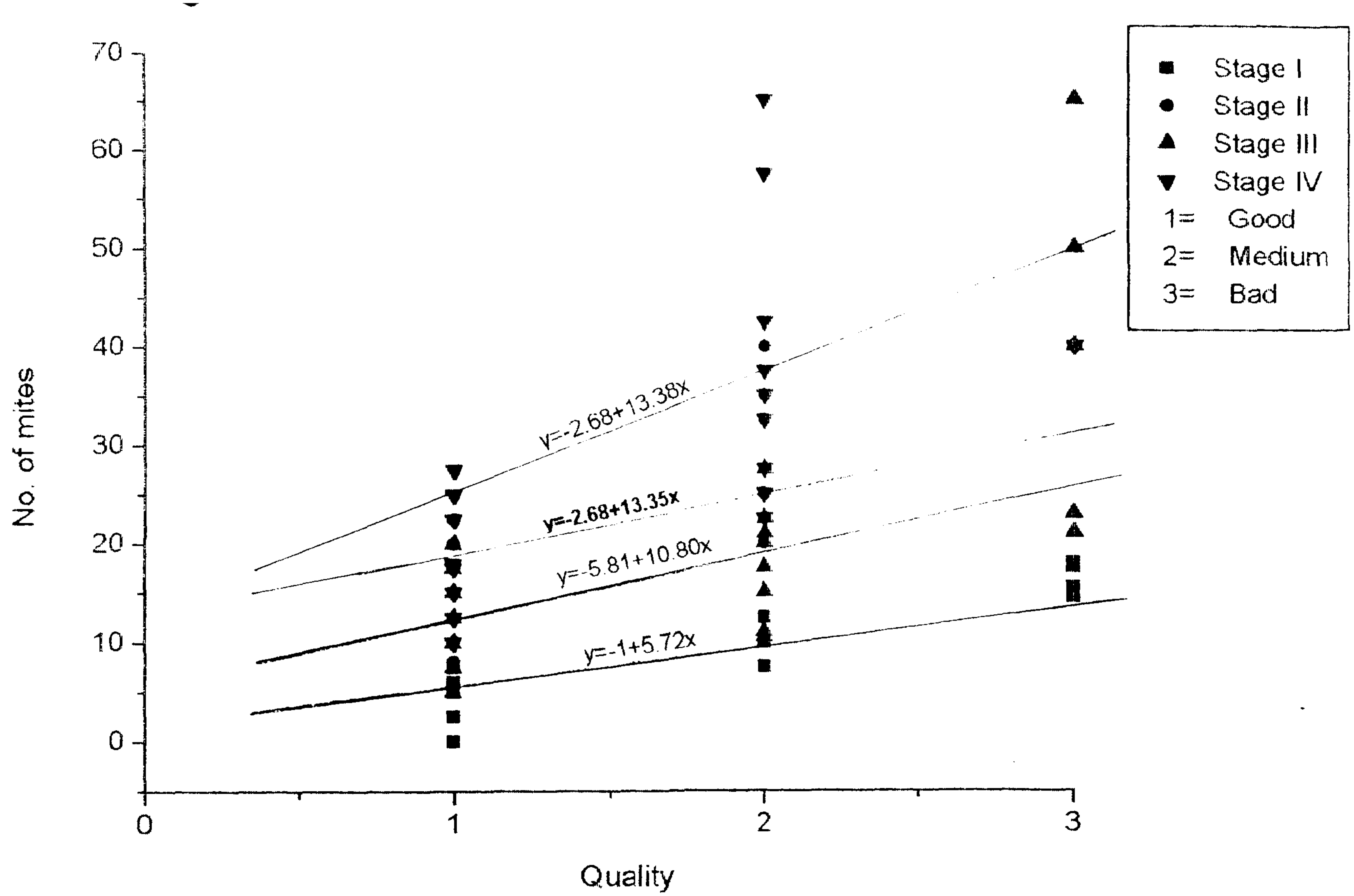


Fig 7. Correlation between number of mites and quality grades at different stages of the flower bud growth.

the time of harvest. But if the population on leaf and flower bud was 10.93 and 20.45, respectively it was found that the flower harvested from such shoots was severely affected, and the quality of the flower was bad.

At stage IV if the population of eggs on leaf and flower bud was 4.30 and 5.45, respectively it was found that the quality of the flower harvested from such shoots was not affected, whereas if the population of eggs was 5.51 and 7.00, respectively the quality of the flower harvested from such shoots was moderately affected, and the quality of the flower was medium. And if the population on leaf and flower bud was 7.03 and 9.52, respectively it was observed that the quality of the flower harvested from such shoots was severely affected and the quality of the flower was bad.

4.3 Management of *T. urticae*, using *Amblyseius longispinosus.* at 20:1 ratio in different varieties of carnation(Table 14.15.16 and 17).

Cabaret :

Before the release of the predators the population of eggs of *T. urticae* was 3.77 per leaf. This population followed the decreasing trend and reached the minimum of about 0.22 per leaf six weeks after release of the predators. The number of nymphs and adults of *T. urticae* before the release of predators was 3.73 and 2.48 per leaf, respectively. This number increased to 3.77 and 2.97 per leaf one week after release of the predators, but later started declining and six weeks after release of predator these were reduced to 0.40 and 0.37 per leaf, respectively. Reduction in the total population. of all the stages of *T. urticae* was observed six weeks after release of the predators.

In the predator free plots the number of egg, nymph and adult stages of *T.urticae* reached the peak 5 weeks after initiation of the study, then started declining. Reduction in the total population of the *T.urticae* in predator free plots was mainly due to unsuitability of the leaves of carnation for multiplication of the spider mite and also due to predation to a little extent, by the phytoseiids, which had moved in from plots on either side where predators were released.

Navajo :

At the time of release of predators the population of eggs of *T. urticae* was 3.58 per leaf. This population started decreasing and reached the minimum of 0.15 per leaf six weeks after release of the predators. The population of nymphs and adults before the release of the predators was 3.65 and 3.28 per leaf, respectively. This population increased to 3.70 and 3.43 per leaf one week after release of the predators, but later started declining and six weeks after release of predator these were reduced to 0.22 and 0.25 per leaf respectively. Reduction in the total population of all the stages of *T. urticae* was observed six weeks after release of the predators.

In predator free plots the population of the eggs, nymphs and adults of *T.urticae* increased and reached the peak population of 6.55, 5.57 and 4.82 per leaf, respectively five weeks after the start of the study. Then this population started declining six weeks after the initiation of the study.

Rirandello:

At the time of release of predators the population of eggs of *T. urticae* was 3.15 per leaf. This population followed the decreasing trend and reached minimum population of 0.20 per leaf six weeks after release of the predators. The population of nymphs and adults before the release of the predators was 3.87 and 2.53 per leaf, respectively. This population increased to 3.92 and 2.93 per leaf one week after release of the predators, but later started declining and six weeks after release of predator these were reduced to 0.77 and 0.58 per leaf respectively. Reduction in the total population of all the stages of *T. urticae* was observed six weeks after release of the predators.

In predator free plots the number of eggs, nymphs and adults of the spider mite during the start of the study was 3.22, 3.23 and 2.85 per leaf, respectively. This number reached the peak five weeks after initiation of the study and started declining six weeks after the start of study.

Feyenoord:

In this variety before the release of predators the number of eggs of *T. urticae* was 3.02 per leaf. This number started decreasing from the first week of predator release and reached the minimum of 0.33 per leaf six after release of the predators. The population of nymphs and adults at the time of release of the predators was 3.17 and 2.70 per leaf, respectively and increased to 3.28 and 2.90 per leaf one week after release of the predators, but later started declining and six weeks after release of predator these were reduced to 0.67 and 0.62 per leaf, respectively. Reduction in the total population of all the stages of *T. urticae* was observed six weeks after release of the predators.

In the plots where the predators were not released, the number of eggs, nymphs and adults of *T. urticae* increased and reached the peak five weeks after the start of study and later the number decreased six weeks after the start of study.

Desio:

At the time of release of the predators the number of eggs was 3.15 per leaf and was reduced to 0.38 per leaf six weeks after the release of the predators. But the population of nymphs and adults increased initially for one week, then gradually decreased to 0.60 and 0.42 per leaf, respectively. Reduction in the total population of all stages was observed six weeks after the release of predators.

In predator free plots the number of nymphs and adults of *T. urticae* increased and reached the peak six weeks after the start of study. But the egg population reached the peak during the fifth week of the study and then started declining six weeks after the start of study.

Grafield:

In this variety before the release of predators the population of eggs of *T. urticae* was 2.83 per leaf. This population started decreasing from the first week of release of predators and reached the minimum population of 0.03 per leaf five weeks after release of predators. The population of nymphs and adults before the release of the predators was 3.02 and 2.18 per leaf, respectively. This population increased to 3.20 and 2.90 per leaf one week after release of the predators, but later started declining and five weeks after release of predators these were reduced to 0.10 and 0.16 per leaf, respectively. Reduction in the total population of all the stages of *T. urticae* was observed five weeks after release of the predators.

In predator free plots the number of eggs and nymphs of *T. urticae* in predator free plots increased and reached the peak five weeks after the start of study, then gradually decreased six weeks after initiation of the study. The adult population followed increasing trend and reached the peak during sixth week of the study.

Furlano:

Before the predators were released population of eggs of *T. urticae* was 3.82 per leaf. This population started decreasing from the first week after predator release and reached the minimum of 0.27 per leaf six weeks after release of the predators. The population of nymphs and adults at the time of release of the predators was 3.57 and 2.82 per leaf, respectively. This population increased to 3.65 and 3.02 per leaf one week after release of the predators, but later started declining and six weeks after release of the predator reduced to 0.57 and 0.28 per leaf, respectively. Reduction in the total population of all the stages of *T. urticae* was observed six weeks after release of the predators.

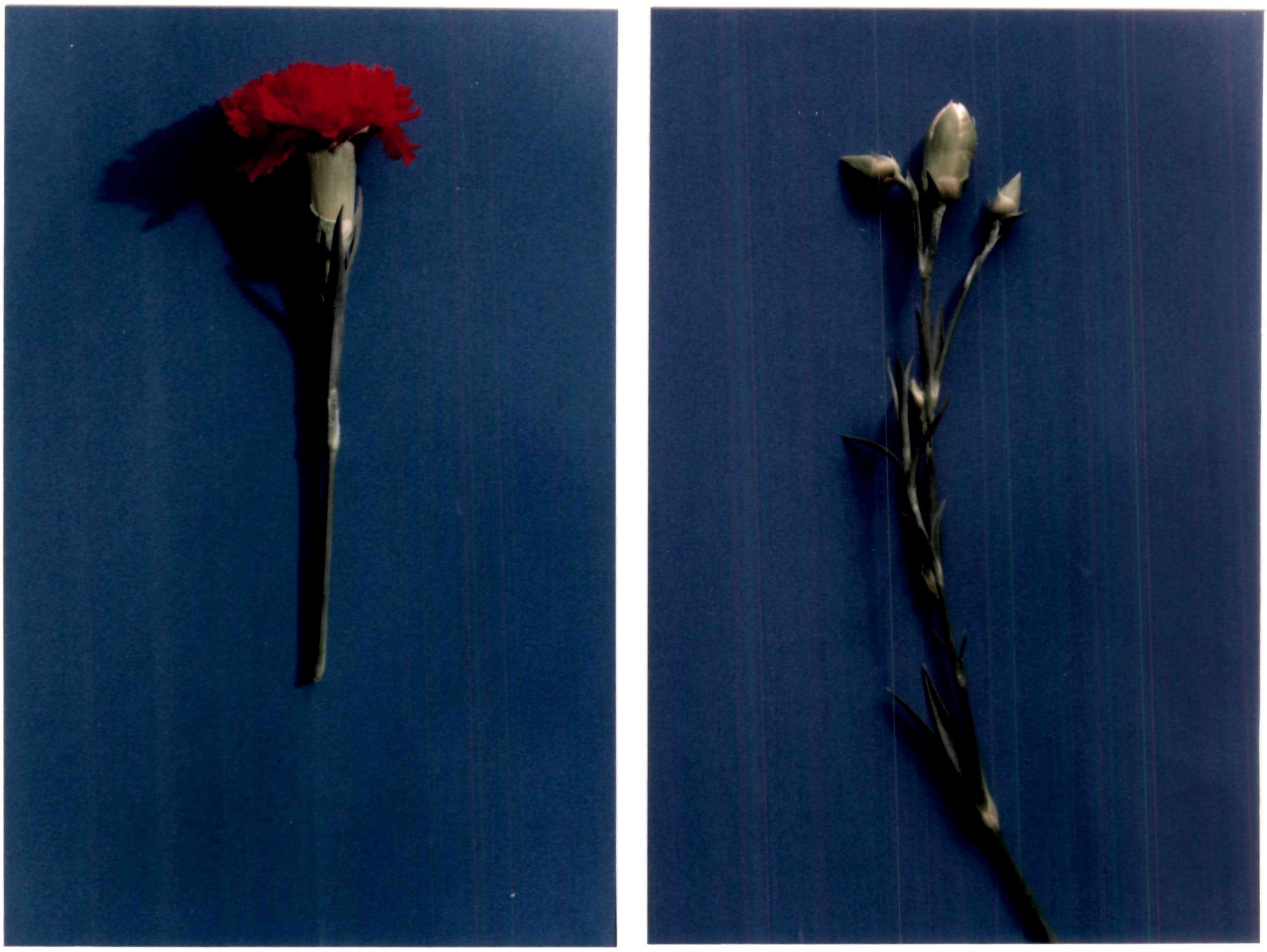
In predator free plots the population of eggs and nymphs of *T.urticae* increased and reached the peak during the fifth week of the study and then started declining six weeks after initiation of the study. The number of adults of *T.urticae* increased and reached the peak population of 4.75 per leaf six weeks after the start of study.

Kartina:

In this variety at the time of release of the predators the population of eggs of *T. urticae* was 3.55 per leaf. This population started decreasing from the first week of predator release and reached zero population five weeks after release of the predators. The population of nymphs and adults before the release of the predators was 3.88 and 2.82 per leaf, respectively. This population increased to 3.93 and 3.18 per leaf one week after release of the predators, but later started declining and five weeks after release of

predator these were reduced to zero. Reduction in the total population of all the stages of *T. urticae* was observed five weeks after release of the predators.

In the predator free plot the number of eggs and nymphs of *T.urticae* increased and reached the peak five weeks after the start of study and later started declining. But the population of the adults reached the peak six weeks later.



Standard type

Spray type

Flowers of standard and spray type variety

Table 14. Population of eggs of *Tetranychus urticae* on carnation plants where *Amblyseius longispinosus* was released at the ratio of 20:1 in different varieties.

Varieties	Number of eggs per leaf						
	Weeks after release						
	Pre release	I week	II week	III week	IV week	V week	VI week
Cabaret	3.77	3.13	2.60	2.4	2.05	1.43	0.22
Control	3.13	3.70	4.55	5.48	6.01	6.57	5.9
Navajo	3.58	3.08	2.63	2.37	2.05	1.37	1.15
Control	3.25	3.48	4.68	5.5	6.12	6.55	5.95
Rirandello	3.15	2.95	2.47	2.1	2.00	1.18	0.20
Control	3.22	3.55	4.58	5.35	5.90	6.17	5.52
Feyenoord	2.77	2.78	2.15	1.92	1.90	1.07	0.33
Control	3.05	3.35	4.43	5.23	5.73	6.10	5.62
Desio	3.15	3.05	2.55	2.27	2.07	1.72	0.38
Control	3.22	3.57	4.73	5.32	5.72	6.23	6.05
Grafield	2.83	2.76	2.43	1.76	0.26	0.03	0.00
Control	2.97	3.27	4.25	4.85	5.2	5.45	5.20
Furlano	3.82	3.68	3.05	2.73	2.52	1.92	0.27
Control	3.72	4.18	5.18	5.75	6.25	6.35	6.02
Kartina	3.55	3.27	2.57	1.2	00.16	0.00	0.00
Control	3.33	3.75	4.73	5.38	5.92	6.05	5.70

Table 15. Population of nymphs of *Tetranychus urticae* on carnation plants where *Amblyseius longispinosus* was released at the ratio of 20:1 in different varieties.

Varieties	Number of nymphs per leaf						
	Weeks after release						
	Pre release	I week	II week	III week	IV week	V week	VI week
Cabaret	3.73	3.77	2.80	2.58	2.50	1.77	0.40
Control	3.52	3.62	4.48	4.83	5.32	5.43	5.17
Navajo	3.65	3.70	2.97	2.47	2.43	1.57	0.22
Control	3.43	4.03	4.50	4.55	5.27	5.57	4.72
Rirandello	3.87	3.92	2.85	2.58	2.56	2.03	0.77
Control	3.23	3.90	4.30	4.68	5.12	5.33	5.03
Feyenoord	3.17	3.28	2.58	2.45	2.33	1.43	0.67
Control	3.23	4.00	4.12	4.53	4.88	5.20	4.83
Desio	3.38	3.40	2.75	2.61	2.40	1.87	0.60
Control	3.48	4.05	4.23	4.73	5.03	5.30	5.17
Grafield	3.02	3.20	2.75	2.65	1.81	0.10	0.00
Control	3.2	3.83	4.05	4.65	4.85	4.93	4.85
Furlano	3.57	3.65	2.73	2.40	2.25	2.05	0.57
Control	3.67	3.93	4.47	4.85	5.28	5.42	5.33
Kartina	3.38	3.93	2.90	2.28	2.00	0.00	0.00
Control	3.12	3.83	4.28	4.77	5.02	5.37	5.10

Table 16. Population of adults of *Tetranychus urticae* on carnation plants where *Amblyseius longispinosus* was released at the ratio of 20:1 in different varieties.

Varieties	Number of adults per leaf						
	Weeks after release						
	Pre Release	I week	II week	III week	IV week	V week	VI week
Cabaret	2.48	2.97	2.50	2.28	2.02	1.30	0.37
Control	2.78	3.42	3.73	4.15	4.47	4.83	4.58
Navajo	3.43	3.43	2.70	2.53	2.05	1.42	0.25
Control	3.27	3.72	3.75	3.85	4.45	4.82	4.33
Rirandello	2.53	2.93	2.47	2.27	2.06	1.40	0.58
Control	2.85	3.58	3.67	4.15	4.43	4.72	4.62
Feyenoord	2.70	2.90	2.23	2.10	2.06	1.57	0.42
Control	2.93	3.38	3.57	3.68	4.02	4.42	4.25
Desio	2.87	2.97	2.50	2.20	2.13	1.42	0.42
Control	2.88	3.47	3.58	3.88	4.15	4.60	4.48
Grafield	2.18	2.90	2.23	2.13	1.56	0.16	0.00
Control	2.92	3.52	3.57	3.85	4.05	4.17	4.33
Furlano	2.82	3.02	3.02	2.65	2.37	1.62	0.28
Control	3.15	3.87	3.95	4.23	4.67	4.75	0.75
Kartina	2.82	3.18	2.73	2.66	2.00	0.00	0.62
Control	2.97	3.80	3.87	4.18	4.60	4.92	4.98

Table 17. Total population of *Tetranychus urticae* on carnation plants where *Amblyseius longispinosus* was released at the ratio of 20:1 in different varieties.

Varieties	Total population per leaf						
	Weeks after release						
	Pre release	I week	II week	III week	IV week	V week	VI week
Cabaret	9.98	9.87	7.90	7.27	6.57	4.50	0.98 (-4.07)
Control	9.43	10.73	12.77	14.47	15.88	16.83	15.65
Navajo	10.52	9.97	8.30	7.37	6.53	4.35	0.62 (-4.46)
Control	9.95	11.23	12.93	13.95	15.83	16.93	15.00
Rirandello	9.55	9.80	7.78	6.95	6.63	4.62	1.55 (-4.11)
Control	9.30	11.03	12.55	14.18	15.45	16.22	15.17
Feyenoord	8.89	8.97	6.97	6.47	6.28	4.07	1.62 (-446)
Control	9.22	10.73	12.12	13.45	14.63	15.72	14.70
Desio	9.40	9.48	7.80	7.08	6.60	5.00	1.40 (-4.59)
Control	9.58	11.08	12.55	13.93	14.90	16.13	15.70
Grafield	8.03	8.86	7.42	6.50	3.61	0.30	0.00 (-4.39)
Control	9.08	10.62	11.87	13.35	14.10	14.55	14.38
Furlano	10.21	10.35	8.80	7.78	7.13	5.58	1.12 (-4.45)
Control	10.53	11.98	13.60	14.83	16.20	16.52	16.10
Kartina	10.25	10.38	8.20	6.66	4.16	0.00	0.00 (-4.31)
Control	9.42	11.38	12.88	14.33	15.53	16.33	15.78

(At six weeks after release: t-test*; CD at P = 0.05)

DISCUSSION

V DISCUSSION

The spider mite, *Tetranychus urticae* is an important pest of carnation and many other flower crops like rose, chrysanthemum, gerbera, *etc.* But the information in India on aspects of biological control is scarce. The present investigation was oriented towards biological control of *T.urticae* using the predatory mite *Amblyseius longispinosus*, on carnation, to develop sampling program for *T.urticae* on carnation and to assess the loss caused due to this mite infestation in carnation. The results of these studies on carnation are discussed with respect to earlier findings on related mite species on other corps.

5.1 Distribution and sampling of *T.urticae* in different varieties of carnation.

The distribution of eggs, nymphs and adults of *T.urticae* followed similar pattern in all the varieties of carnation included for the study. The population of eggs, nymphs, and adults were higher on the top canopy leaves followed by middle and bottom canopy leaves. Within each leaf, the upper surface harboured more number of eggs, nymphs and adults followed by lower surface of the leaf. If the whole plant is considered the upper surface of the top canopy leaves had the highest number of different stages of the spider mite and lower surface of the bottom canopy leaves had the lowest number of eggs, nymphs and adults. Among all the varieties, variety Furlano had highest total population of the spider mite and the variety Riarandello had lowest total population. The mean number of eggs, nymphs and adults per leaf of the bottom, middle and top canopy was less than the variance. This shows that the distribution is clumped. The population of different stages of the spider mite on the upper and lower surface of the bottom and middle canopy leaves had low correlation with the total population. The population of different stages of the mite in the upper surface had high correlation with total population in most of the varieties further the coefficient of variation was lower in these populations and, hence this leaf surface can be considered as the most appropriate sample in a sampling program, whereas the population on lower surface had high correlation with the total population. The population on lower surface of the top canopy leaves showed high correlation with the total population compared to other surface.

Krainacker and Carey (1990) observed that the aggregation of *Tetranychus urticae* was more on the bottom canopy leaves of the corn plants, early in the season and on the middle canopy leaves towards the end of the season. They suggested that mites sampling should be focused on the number of females on the bottom canopy leaves, early in the season and on the middle canopy leaves during the end of the season.

Anon (1998) has similarly reported that aggregation of *T.urticae* was more on the middle canopy leaves of the bean plants followed by bottom canopy leaves. Onkarappa (1999) reported aggregation of *T.urticae* on bottom canopy leaves of the rose plants grown in the open field condition, he opined that rose being a shrub the senescence of the leaves is much slower than in annuals like French bean, hence the mite prefers the bottom canopy leaves.

Ramesh Vaidya (1999) observed higher aggregation of *T.urticae* on middle canopy leaves of the rose plants grown in polyhouse condition. According to him the growth of the rose plants within polyhouses is faster compared to plants grown in open field, hence the bottom canopy leaves attain senescence early, as a result the mites avoid the bottom canopy leaves and prefer the middle canopy leaves. Growth of carnation plants in polyhouses is similar to that of rose, hence the bottom canopy and middle canopy leaves attain senescence early compared to top canopy leaves, as a result the mites avoid the bottom and middle canopy leaves and prefer the top canopy leaves.

5.2 Crop loss estimation.

5.2.1. Population of mites on harvested flowers of different quality grades in different varieties of carnation.

In all the varieties of carnation, bad quality flowers had significantly more number of mites followed by medium and good quality flowers. The number of mites on the bad quality flowers of different varieties ranged from 23.00 to 46.92 per flower, the lowest number per flower was recorded on the variety Desio, and variety Cabaret recorded highest number of mites per flower.

The number of mites on medium quality flowers of different varieties ranged from 17.50 to 27.75 per flower. The variety Desio had the lowest number of mites on the flowers and the highest numbers of mites per flower was recorded on variety Cabaret.

The number of mites on different varieties on good quality flowers ranged from 6.95 to 12.32 per flower, the lowest number was recorded in the variety Kartina whereas the highest number was recorded in the variety Cabaret. The variety cabaret appeared to be more resistant than others and variety Desio was highly susceptible, since lower populations of the mites could affect the quality of the flowers.

5.2.2 Flower grade categories and loss in different varieties of carnation

The percentage of bad quality flowers was more in the variety Kartina (20.75%) followed by the varieties like Grafitti (19.23), Feyenoord (18.91). Grafield (18.36), Cabaret (17.80), Desio (16.49), Navajo (15.60), whereas varieties Rirandello (14.28) and Furlano (14.28) recorded lowest percentage of bad quality flowers.

Medium quality flowers percentage was more in the variety Feyenoord (19.81) followed by the variety Grafield (19.38), Kartina (18.86), Cabaret (17.80), Furlano (16.19), Desio (15.46), Navajo (14.89), Rirandello (13.90), the variety Grafitti (7.69) recorded the lowest percentage of medium quality flowers.

The variety Grafitti was damaged less by the mites since the highest percentage (73.07) of good quality flowers was recorded in this variety followed by varieties like Rirandello (71.30), Furlano (69.52), Navajo (69.50), Desio (68.04), Cabaret (64.38), Grafield (62.24). Feyenoord (61.26) and Kartina which had lowest percentage of (60.32) good quality flowers were highly susceptible to damage by the mite.

Attiah *et al.*, (1976) reported the effect of three levels of infestation by the spider mite *Tetranychus arabicus* on quality of Egyptian cotton. Mite infestation reduced the seed cotton yield in all the varieties. Similarly in the present study spider mites affected the quality of the flower but to varying degrees.

The per cent monetary loss was computed in the different varieties of carnation included in the study. The per cent monetary loss was computed based on the selling price for different quality flowers. The highest per cent monetary loss was recorded in the two variety Kartina (29.80) and Feyenoord (28.41), whivh were susceptible to mite damage, followed by Grafield (27.60), Cabaret (26.34), Desio (23.90), Grafitti (22.92), Navajo (22.74) Furlano (22.05), and the variety Rirandello recorded lowest per cent monetary loss (20.58). Doncanerday and Arrant (1964) reported the effect of spider mite, *Tetranychus cinnabarinus* population on yield and quality of cotton in their field experiments. Their experiments with artificially established infestations at different times of the growing season showed reduction in the yield of seed cotton from 14 to 44%. In the present study natural infestations of spider mite reduced monetary returns from 20.58 – 28.41%.

5.2.3 Stage related losses

The studies on stage wise related loss showed that the plants can tolerate an average (total) population of 12.15 to 14.43 mites per leaf, since the plants at the different stages with such low initial population were able to put forth good quality flowers. When the population of the mite was above 15 but lower than 20 the damage to the flowers was not severe. Plants with this level of population were able to put forth flowers, which were of medium quality or those that fetched half the price. When the population crossed 20 mites per leaf at any of the stage of the plant the harvested flowers showed complete damage and these had to be rejected. However, the population on the leaves during all the stages could not be related to the flower quality since plants in the fourth stage actually had less number of mites. The population had declined either due to migration to adjoining shoots or to the flowers to enable their dispersal by migration. The population of mites on flower buds and flowers, in all the four growth stages, on the other hand, showed positive relationship to the quality of harvested flowers.

The different stages of the mite, i.e., eggs, nymphs and adults followed similar trend. Since counting the adults *insitu* is easier, the population of adults on the developing flower buds can be used as a reliable index to predict flower quality and initiate control programmes.

Catsanera and Arroyo (1979) infested dwarf greens with *T. cinnabarinus* per dwarf green plants during three leaf stage with 6, 20 or 60 females. It was found that an initial infestation of 6 mites / plant caused insignificant damage but initial levels Of 20 or 60 females significantly reduced the yield. In the present study 6.95-12.32 mites per flower did not affect the quality of the flower but 17.50-46.92 mites/ flower affected the quality of the flower in terns of low monetary returns.

5.3 Management of *T.urticae* using *Amblyseius longispinosis* released at the ratio of 20:1 on different varieties.

In case of standard type varieties, *viz.*,Cabaret, Navajo, Rirandello, Feyenoord, Desio and Furlano, *Amblyseius longispinosus* caused maximum reduction of *T.urticae* six weeks after release. In spray type varieties like Grafield and Kartina *Amblyseius longispinosus* was able to bring about reduction of *T.urticae* populations within 5 weeks of release. Standard type varieties had more number of shoots and leaves per shoot while spray type varieties had significantly less number of shoots per plant and leaves per shoot. In all the varieties reduction in the number of eggs of *T. urticae* was observed one week after the release of predators. But the population of nymphs and adults increased for one week after the release of the predators, and then gradually decreased in all the varieties. This is because predators preferred to feed on eggs than nymphs and adults of *T. urticae*.

In control plots of the standard type varieties the number of eggs, nymphs and adults of the spider mite increased upto five weeks, later the population of the spider mite decreased gradually whereas, in spray type varieties the number of eggs, nymphs and adults of the spider mite increased upto four weeks, later the population of the spider mite gradually declined. The decline in the population of the spider mite in all the varieties was due to the deterioration of plant condition which was not suitable for further multiplications of the mites and also due to the movement of predators from released plots to control plots.

Killincer *et al.*, (1992) reported that the release of 15, 60, 20, and 40 phytoseiids suppressed the *Tetranychus* sp. population. In the present study predators released at 1:20 predator to prey ratio and suppressed the *T. urticae* population five and six weeks after the release in standard and spray type varieties, respectively. Wilson *et al.*, (1984) obtained good control of *Tetranychus* sp. on almond within two weeks by releasing *Metaseiulus occidentalis* at the ratio of 1:10 predator : prey.

Poe *et al.*, (1976) achieved good control by releasing one predator (*Phytoseiulus presimilis)* to 16 prey mites (*T. urticae*) on strawberry. Onkarappa (1999) obtained the maximum reduction of *T. urticae* by releasing the *A. longispinosus* at the ratio of 1:300, two weeks after the release.

SUMMARY

VI SUMMARY

The present investigations were conducted to know the distribution of the spider mite, *Tetranychus urticae* Koch infesting carnation in greenhouse, evolve a sampling technique for the spider mite, to asses the loss caused due to mite infestation and to investigate possibility of using the phytoseiid predator, *Amblyseius longispinosus* for managing this pest in green house condition. The studies were conducted at Rashmi farm of Indo- American hybrid seeds (Pvt.) India Ltd., at Kengeri, Bangalore during 1999-2000. The results of the investigations are summarized below.

Eggs, nymphs and adults of *Tetranychus urticae* were comparatively more abundant on the leaves of the top canopy compare to middle and bottom canopy leaves. The upper surface of the leaves harboured more number of mites compared to lower surface of the leaf. The mean number of eggs, nymphs and adults per leaf of the bottom, middle and top canopy leaves was more than the variance, indicating that the distribution was clumped.

Coefficient of variation for the population of different stages of *T. urticae* on different leaf surfaces of top, middle and top canopy was computed. Number of different stages of the spider mite on each surface of leaf was correlated with total population of the respective stages present on the plant. The upper surface of the top canopy had high correlation value with the total population compare to other leaf surface and also different canopy levels of the plant. Thus upper leaf surface of the top canopy leaf is most appropriate for sampling.

At the growth stage I of the shoots (flower size – 10.27 mm) the threshold or critical level of mites (all stages) on leaf and flower was 15.32 and 9.62, respectively whereas, at the growth II (flower size – 15.46 mm) it was 15.91 and 14.12, respectively. But at the growth stage III (flower size – 16.51 mm) the threshold level was 17.09 and 22.47 mites on leaf and flower bud respectively and at the stage IV (fully opened flower) the number was 14.38 and 26.20, respectively.

Bad quality flowers had significantly more number of mites (34.64) per flower followed medium (21.33) and good (9.25) quality flowers in all the varieties of carnation included for the study.

The highest percent monetary loss was obtained in the variety Kartina whereas the lowest percent monetary loss was observed in the variety Rirandello.

In spray type varieties, *A. longispinosus* was able to effectively bring down the population of *T. urticae* within five weeks of release when they are released at the ratio of 1:20 whereas in case of standard type varieties it was observed that six weeks after the release of predators, the population of *T.urticae* was eliminated.

REFERENCES

VII REFERENCES

* Amano, H. and Chant, D. A., 1977. Life history and reproduction of the two species of predaceous mites, *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius andersoni* (Chant) (Acarina : Phytoseiidae). *Can. J. Zool.*, **55:** 1978-1983.

*Anderson, V.S., 1947. Unter Suchungen uber die Biologie and Bekampfung der obstbaumspenn milbe, *Paratetranychus pilosus. Can. Et Fanz Dis. Univ. Bonn,* pp.118

Anil, K.N., 1990. Biological and chemical control of *Oligonychus indicus* (Hirst) (Acari : Tetranychidae) on areca. M.Sc(Agri) thesis, University of Agricultural Sciences, Bangalore. pp. 57-59.

* Anonymous., 1998. Progress report 1996 – 98. All India Co-ordinated Research Project On Agricultural Acarology, Bangalore. pp. 280.

Arun kumar, N., 1996. Effect of feeding by the spider mite *Tetranychus urticae* Koch (Acari : Tetranychidae) on physiological activity of leaves and yield of french bean (*Phaseolus vulgaris* L.). M. Sc.(Agri) thesis, submitted to Dept. of Entomology., University of Agricultural Sciences, Bangalore, 1996.

* Ashihara, W., Inoue, K., Osakabe, M. and Hamamura, T., 1992. Effectiveness of *Phytoseiulus persimilis* Athias-Henriot (Acarina : Phytoseiidae) as a control of agent for the Kanzawa spidermite, *Tetranychus kanzawai* Kishida (Acarina : Tetranychidae) and occurrence of native natural enemies of the spidermite on grapevine in glass house. *Bulletin of the Fruit Tree Research Station*, **22**: 109-130.

Asquith, D., 1968. European red mite and two spotted spider mite control on apple trees. *J. Econ. Entomol.*, **61** (8) : 1044 – 1046.

* Atanasov, N., 1983. Mites on fruit crops, *Rostitelna zashchita*, **31**(8): 7-9.

*Attiah, H. H., El-kifl, A. H. and Hoda, F. M., 1976. The effect of infestation with spider mite (*Tetranychus arabicus.* Attiah) on quantity and quality of cotton yield. *Bull. Soc Ent. Egypt.*, **60** : 95-105.

*Avery, D. J., 1962. The vegetative growth of young plants of Brompton plum infested with fruit tree spider mites. *Bull. Rep. E. Malling Res. Sta.* for 1961 : pp 227-253.

Avery, D. J. and Briggs, J. B., 1968a. Damage to leaves caused by fruit tree spider mite Panonychus ulmi (Koch). J. Hort. Sci.* **43**: 463-473.

Avery, D. J. and Briggs, J. B., 1968b. The etiology and development of damage in young fruit trees infested with fruit tree spider mites, *Panonychus ulmi* Koch. *Ann.Appl. Biol.* **61** : 277-278

Baker, J. E. and Connell, W. A., 1963. The morphology of mouthparts of *Tetranychus atlantius* and other observations of feeding by this mite on soybeans. *Ann. Ent. Soc. Am.*, **56** : 733-736.

Banerjee, B., 1971. The threshold values in the mire pest control. *Two Bud.*, **18** (1) :20-21.

Bechinski, E. J. and Stoltz, R. L., 1985. Presence absence sequential decision plan for *Tetranychus urticae* (Acari : Tetranychidae) in garden seed beans *Phaseolus vulgaris. J. Econ. Entomol.*, **78**(6): 1475-1480.

Bhatt, N.R., 1989. Carnation. *In Commercial flowers,* eds.Bose, T. K. and Yadav, B.P., Calcutta, pp. 335-357.

*Blair, C.A., 1951. Damage to apple leaves by the fruit tree red spider mite *Metatetranychus ulmi*. Koch.. *Ref. E. Malling Res. Sta.*, for *1950*, pp 152-154.

Blommers, L., 1976. Capacities for increase and predation in *Amblyseius* sp. (Acarina : Phytoseiidae) as predators on orchard mites. *Ann. Entomol. Soc. Am.*, **57:** 483-487.

*Bondarenko, N. V and Asatur, M. K., 1960. Peculiarities in the bionomics of the red fruit tree mite (In Russian). *Zap. Leningr. S. Kh. Inst:*, **80** :73-83.

*Boulanger, L W., 1958. The effect of European red mite feeding injury on certain metabolic activities on red delicious apple leaves. *Maine. Agric. Expt. St. Bull.* **370** :34 PP.

Braun, A. R., Guerrero, J. M., Bellotti, A. C. and Wilson, L. T., 1987. Relative toxicity of permethrin to *Mononychellus progresivus* Doreste and *Tetranychus urticae* Koch (Acari: Tetranychidae) and their predator *Amblyseius limonicus* Garman and Mc Gregor (Acari : Phytoseiidae) and *Oligota minuta* Cameroon (Coleoptera : Staphylinidae) : Bioassays and field validation . *Environ. Entomol.*, **16** (2) : 545 – 550.

Briggs, J. B. and Avery, D.J., 1968. Effects of infestation with fruit tree red spider mite *Panonychus ulmi* (Koch) on the growth and cropping of young fruit trees *Ann. Appl. Biol.*, **61** : 269-276.

*Cai, N. H., Quin, Y. C. and Hu, D. X., 1992. Evaluations of the damage of two spider mite species to apple tree. *Acta. Phytophylactica. Sin.*, **19** (2) : 165-170.

* Castagnoli, M., Liguori, M. and Simoni, S., 1993. Distribution, sampling and association of soybean mites in Italy. *Redia*, **76**(1): 111-112.

*Castanera, P. and Arroya, M., 1979. Influence of the level of infestation by the red mite *Tetranychus cinnabarinus* (Boisduval) on dwarf green beans. *Prot. Veget.*, 11: 93-102.

Chapman, P. J., Lieuk, S.E. and Curtis, D. F., 1952. Responses of apple trees to mite infestations. *I. J. Econ. Ent.*, **45** : 815-821.

*Cory, E.N., 1922. The control of insects in 1921. *Rep. Md. Agric. Soc.*, **6**: 159-168

*Cottier, W., 1934. The European red mite in New Zealand. *N. Z. J. Sci. Tech.*, **16**: 36-56

Devi, D. A., and Rai, S., 1996. Spatial distribution of *Tetranycus cinnabarinus* and *Amrasca biguttula biguttula* on Okra-A field implementable sequential count plan. *Indian J. Ent.*, **58**(3): 203-209.

Dhooria, M. S., 1985. Effect of releasing different levels of red spider mite, *T. cinnabarinus* (Boisd.) on growth of brinjal and okra plants. *Acarology News Let.*, **15** : P.3

Doncanerday, T. and Arant, F. S., 1964. The effect of spider mite population on yield and quality of cotton. *J. Econ. Ent.*, **57** (4) : 553-556.

Duso, C., 1989. Role of the predatory mites *Amblyseius aberrans* (Oud.), *Typhlodromus pyri* Scheuten and *Amblyseius andersoni* (Chant) (Acari : Phytoseiidae) in vineyard. The effect of single or mixed phytoseiid population releases on spidermite densities (Acari : Tetranychidae). *J. Appl. Entomol.*, **107**(5): 474-492.

*Ehler. L.E., 1974. A review of the spider mite problem on grain sorghum and corn in West Texas. *Texas Agric. Expt. Stn. Bull.* **1149** :15.

*El-lathy, A. V. M., 1992. Some aspect on the use of the predaceous mite *Phytoseiulus persimilis* Athias-Henriot for biological control of the two spotted spidermite *Tetranychus urticae* Koch in green houses in Egypt. *Zeitschrisft fur Pflanzenkran kheitten und pflanzenschutz*, **99**(1): 93-100.

Furr, R. E. and Pfrimmlr, T. R., 1968. Effect of early, mid and late season infestation of two spotted spider mites on the yield of cotton. *J. Econ. Ent.*, **61** (5) : 1446-1447.

Ganok, V., 1982. Preliminary study on the biology of cassava red mite *Tetranychus truncatus* Ehara (Acarina : Tetranychidae) and the predaceous mite *Amblyseius longispinosus* (Evans) (Acarina : Phytoseiidae). (In Thai). Mag. Sc. Thesis, Kasetsart University, Bangkok, Thailand. 79pp.

Gonzalez-Zamora, J. E., Gareio-Mari, F., Ribes, A., Saques, J., Masiello, L. and Orenga, S., 1993. Bionomial and sequential sampling programmes for *Tetranychus urticae* Koch (Acari : Tetranychidae) and *Amblyseius californicus* (McGregor) (Acari : Phytoseiidae) on strawberries. *Boletin-de-Sanidad-Vegetal, Plagas.*, **34**: 559-586.

Gowda, J. V. N. and Jayaprasad, K. V., 1997. Floriculture in India, *Abstracts of papers presented at seminar " Flora 97"* Bangalore, October 3-5, 1997.

Gupta, S. K., 1986. Fauna of India, Acari : Mesostigmata (Family : Phytoseiidae). *Zoological Survey of India*, Calcutta, pp. 350.

*Hammer, D.H.,1943. Some facts and observations regarding summer control of red mite. *Pro.N.Y.State Hort. Soc.* **88**:174-180

*Hance, T., Lebran, P., Nihoul, P., Benoit, F., Ceustermons, N. and Van-Impe, G., 1991. Comparison of the efficacy of a chemical control technique and a biological control for protection of the cultivation of tomato against the spider mite *Tetranychus urticae* Koch (Acari : tetranychidae). *Agronomie.*, **11** (9): 799-806.

Hardman, J. M., Hebbert, H. J., Sanford, K. H. and Hamilton, D., 1985. Effect of populations of the European red mite, *Panonychus ulmi* on the apple variety red delicious in Novascotia. *Can. Ent.*, **117** (10) : 1257-1265.

Hart, R. N. S., 1987. Biological control of two spotted spidermite *Tetranychus urticae* on ornamental nursery plants using the predatory mite *Phytoseiulus persimilis.* Howkesbury Agricultural Coll., Manila (Philippines). **24**: 2 pp.

Hepworth, C.F. and MacFarland, J. R., 1992a. Variance of the estimated population density from a presence absence sample. *J. Econ. Entomol.*, **85**(6): 2240-2245.

Hepworth, G. and MacFarlane, J. R., 1992b. Systematic presence absence sampling method applied to two spotted spidermite (Acari : Tetranychidae) on strawberries in Victoria, Australia. *J. Econ. Entomol.*, **85**(6): 2234-2239.

*Hirschberger, G. and Kremheller, H. T., 1993. Biological Control of red spidermite (*Tetranychus urticae*) in hops. *Gesunde Pflanzen*, **45**(3): 96-98.

*Holanda, A., Olivevira, J. V. and Silva, I. P., 1992. Losses caused by *Polyphagotarsonemus latus* (Banks), (Acari : Tarsonemidae) and *Tetranychus desertorum* (Banks,) (Acari : Tetranychidae) to beans *Phaseolus vulgaris*. L. and *Vigna ungiculata*. L. Walp. *Anais das. Entologica do Brasil.*, **21** (1) : 115-134.

Holling, C. S., 1959. The components of predation as revealed by a study of small mammal predation of European pine sawfly. *Can. Ent.*, **91**: 293-320.

Hoy, M. A., 1985. Almonds (California). In: W. Helle and M. W. Sabelis (Eds.), *Spider mites their biology, natural enemies and control*, Elsevier, Amsterda, The Netherlands. Vol. **1**B, pp. 299-310.

Huffaker, C. B. and Spitzer, C. J., 1950. Some factors affecting red spider mite population on pears in California. *J. Econ. Ent.*, **43** : 819-831.

Huffaker, C. B., Van de Vrie, M. and McMurtry, J. A., 1970. Ecology of Tetranychid mites and their natural enemies : A review II. Tetranychid populations and their possible control by predators. An evaluation. *Hilgardia*, **40**(11): 391-458.

*Hulchy, M. and Pospisil, Z., 1992. Damage and economic injury levels of Eriophyid and Tetranychid mites on grapes in Czechoslovakia. *Exp. Appl. Acrol.*, **14** (2) : 95-106.

Hussey, N. W. and Parr, W. J., 1963. The effect of glass house red spider *Tetranychus urticae* Koch on the yield of cucumbers. *J. Hort. Sci.* **38** : pp 255-263.

*Hussey, N. W. and Parr, W. J., 1965. The role of leaf damage assessment in the control of glass house red spider mite on cucumbers : *Proc. Third British Insecticides and Fungicides Conf.*, 317-322.

Jeppson, L. R., Keifer, H. H. and Baker, E. W., 1975. Mites injurious to economic plants. *Uni. Calif. Press.* pp. 614.

*Jesitor, L.J., 1976.The injurious effects of the two spotted spider mite (*Tetranychus urticae* Koch.) on green house carnations. *Ekol.pol.*, **24**(3): 413-419

Jones, V. P., 1990. Sampling and dispersion of two spotted spider mite (Acari: Phytoseiidae) on tart cherry. *J. Econ. Entomol.*, **83** (4): 1376-1380.

*Kilincer, N., Cobanoglu, S. and Has, A., 1992. Studies on the potential of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot (Acarina : Phytoseiidae) as a biological control agent on various crops in the green house. *Proceedings of the Second Turkish National Congress of Entomology*. Bitki Koruma Bolomu Ankara, Turkey, pp 109-122.

Kolbe, W., 1968. Unter suchungen uberdas obstaaumspennmilbe, *Panonychus ulmi* Koch. *Erwerbobstbau*, **10**: pp 41-46

*Kongchuensin, M., Charanasri, V., Kulpiyawat, T. and Knantonthon, P., 1988. Biological control two spotted spider mite in strawberries by predatory mite *Amblyseius longispinosus* (Evans.). *10th International Congress of Acarology Abstracts*, Canberra, Australia, July 5-10, 1998.

*Koppert, P.C., 1980. Biological control in glass houses in Netherlands. **In**: *Proc. Int. Symp. IOBC/WPRS on Integrated Control in Agriculture and Forestry*, Vienna, 8th - 12th October, 1979, pp. 484.

Kovach, J. and Gorsuch, C. S., 1985. Effect of *Tetranychus urticae* populations on peach production in South Carolina. *J. Agric. Ent.*, **2**(1) : 46-51.

Krainacker, D. A. and Carey, J. R., 1990. Spatial and termporal dynamics of two spotted spidermite, *Tetranychus urticae* Koch (Acari : Tetranychidae) *J. Appl. Ent.*, **109**(5): 481-489.

*Kuenen, D. J., 1946. Hot fruit spent enzijn bestrijdung meded. *Tuinbvoorl. Diest.* **44**: pp 68.

*Leigh, T. F., 1963. Considerations of distribution, abundance and control of acarine pests of cotton. **In**: *Advances in Acarology* I. Ithaca, N. Y., Cornell University Press.pp 14-20.

Lienk, S.E., Chapman, P.J. and Curtis, O.F., 1956. Response of apple trees to mite infestations. II. *J. Econ. Ent.*. **49** : 350-353.

*Liesering, R., 1960. Beitrag Zum phytopathologischen Wirkungsmechanisman van. *T. urticae* Koch (Acari : Tetranychidae *) Z. pflxrankh pflpath. pflfechutz.*, **67** : 524-542.

Mallik, B., 1974. Biology of *Amblyseius longispinosus* (Evans.) (Acarina : Phytoseiidae) and interaction between them. M. Sc. (Agri.) thesis. Department of Entomology, UAS, Bangalore.

Mallik, B., Onkarappa, S. and Harishkumar, M., 1998. Management of spider mite *Tetranychus urticae* Koch. on rose using phytoseiid predator *Amblyseius longispinosus* (Evans) in polyhouse. *Pest manag. Hort. Ecosyst.*, **4** (1): 46-48.

Mallik, B., Ramesh Vaidya and Harish kumar, M., 1999. Mass production of the predator *Amblyseius longispinosus* (Acari : Phytoseiidae) – A Model. *J. Acarology,* **15** (1& 2) : 15-76.

Manjunatha, M., 1988. Bioecology of sorghum spidermite *Oligonychus indicus* Hirst (Acari : Tetranychidae) and estimation of crop losses due to it in sorghum. Ph. D. thesis, University of Agricultural Sciences, Bangalore.

*Mari, F. G. and Comelles, J.C., 1992. Study of the distribution and development of a sampling method for populations of *Panonychus ulmi* in apples. *Bulletin- de-Sanidad -Vegetal Plagas*, **81**(1): 101-114.

*Masis, C. and Aguilar, H., 1990. Control of the mite *Tetranychus urticae* Koch in strawberries (*Fragaria* sp.) in Costa Rica. *Manejo Integrado de plogas*, **17**: 5-7.

*McGregor, E. A and Mc Donough, F., 1917. The red spider mite on cotton. *USDA. Bull.* 416 : pp 72. Mc Whorter, G. M., 1976. Insects and mite pests of field corn fact sheet L. 1417. *Texas A and M University, College station,* pp 4.

McMurtry, J. A., Huffaker, C. B. and Van de Vrie, M., 1970. Tetranychi enemies : their biological characters and the impact of spray practices. *Hilgardia*, **40**(11): 391-445.

Mital, V. P., Kadam, J. R. and Desai, K. B., 1981. Control of sorghum mite (*Oligonychus indicus*) in South Gujarath. **In**: ChannaBasavanna, G. P., Mallik, B. and Kumar D. Ghorphade (Eds.), *Contributions to Acarology in India*, Acarological Society of India, Bangalore, pp.193-203.

Murega and Khaemba, 1985. The effects of infestation by red spider mite, *Tetranychus* sp. (Acarina : Tetranychidae) on the growth and yield components of cotton in Eastern Kenya. *Insect. Sci. Appl.*, **6** (1) : 7-10.

Narayana Gowda, J.V.and Jayaprasad, K.V., 1997. Floriculture in India, *Abstracts of papers presented at seminar Flora 97,* Banaglore, 1997, *Abst.*1-10

*Nicoli, G. and Benuzzi, M., 1988. Biological control of *Tetranychus urticae* Koch with *Phytoseiulus persimils* Athias-Henriot on cucumber in glasshouse crop. *Infromatore fitopatologica,* **38**(3): 53-59.

Nihoul, P. and Hance, T., 1993. Use of a damage index to evaluate the biological control of two spotted spider mite *Tetranychus urticae* Koch (Acari : Tetranychidae) on tomato crops. *J. Hort. Sci.*, **68** (4): 575-580.

Nihoul, P. and Van- Impe, G., 1991. Control of *Tetranychus urticae* (Acari : Tetranychidae) with *Phytoseiulus persimilis* Athias-Henriot (Acari : Phytoseiidae) in tomato crops under glass. *Meded. Fac. Landobuwwet. Rijksuniv. Gent.* **26** (20) : 319-324.

Nihoul, P., 1993. Asynchronous populations of *Phytoseiulus persimilis* Athias-Henriot and effective control of *Tetranychus urtiace* Koch on tomatoes under glass. *J. Hort. Sci.*, **68** (4) : 581-588.

Nikolov, N., Khinkin, S. and Straka, F., 1983. Spider mites as pests of maize. *Rasteniev dni Nauki*, **20** (5) :31-38.

Nyrop, J. P., Agnello, A. M. Kovach, J and Reissig, W.H., 1989. Binomial sequential classification sampling plans for European red mite (Acari : Tetranychidae) with special reference to performance criteria. *J. Econ. Entomol.*, **82** (2) : 482-490.

Nyrop, J. P. and Binns, M. R., 1992. Algorithm for computing operating characteristic and average sample number functions for sequential sampling plans used for binomial count models and revised plans for European red mite (Acari : Tetranychidae) . *J. Econ. Entomol.*, **85** (4) :1253-1273.

Oatman, E. R., Sances, F. V., Lapre, L. F., Toscano, N. C. and Voth, V., 1982. Effects of different infestation levels of the two-spotted spider mite on strawberry yield in winter plantings in Southern California. *J. Econ. Ent.*, **75** (1) : 94-96.

Oatman, E. R., Gilstrap, F. E. and Voth, V., 1976. Effects of different release rates of *Phytoseiulus persimilis* (Acarina : Phytoseiidae) on two spotted spider mite on strawberry in Southern California, *Entomophaga*, **21** :269-273.

Oatman, E. R., Wyman, J. A., Browninig, H. W. and Voth, V., 1981. Effects of releases and varying infestation levels of the two spotted spider mite on straw berry yield in Southern California. *J. Econ. Entomol.*, **74** :1120115.

Oatman, E. R., Wyman, J. A., Browning, H. W. and Voth, V., 1982. Effects of releases and varing infestation levels of the two spotted spider mite on strawberry yield in Southern California. *J. Econ. Ent.*, **74** (1) : 112-115.

Onkarappa, S., 1999. Management of two spotted spider mite, *Tetranychus urticae* Koch. (Acari : Tetranychidae) on rose. Ph. D. Thesis. Department of Entomology, University of Agricultural Sciences, Bangalore.

Oomen, P. A., 1984. Relation of scarlet mite(*Brevipalpus phoenicis*) density in tea with injury and yield. *Netherland J. Pl. Path.*, **90** (5) : 199-212.

Pandey, Y. D, and Sharma, B. L., 1984. Record of some new predators of *Tetranychus neocaledonichus* (Acarina : Tetranychidae) from India. *Sci, Cult.*, **50** (5) 175-176.

*Papaoannou and Soulioti, P., 1979. Effects of the population of Tetranychus urticae (K.) on bean plants (Phaseolus vulgaris L.) *Ann. Inst. Phytopathol. Benaki.*, **12** (1) : 138-143.

Parella, M. P., McMurtry, J. P. and Hors burgh, R. L., 1980. Compatibility of *Lepthrips mali* with *Stethorus punctum* and *Orius insidiosus* predators of *Panonychus ulmi. Environ. Entomol.*, **9** (5) :694-696.

*Parr, W. J. and Hussey, N. W., 1962. Responses of the cucumber plant to different levels of artificial leaf damage in an attempt to stimulate the effect of red spider mite. *Rep. Glass house crops Res. Inst.*,pp 95-99

*Parr, W. J. and Hussey, N. W., 1969. Biological control of spider mites on cucumber: effect of different predator densities an introduction. *Rep. Glass house, Crops Research Institute*, 1966-1967 : pp. 135-139.

Pasqualini, E. and Antropoli, A., 1994 *Stethorus punctillum. Informattore fitopatologica*, **44** (5) : 33-36.

Pasvhoal, A. D., 1970. Contribuico ao conhecimento de famila Tetranychidae no Brasil (Arachnida : Acarinas) *Tese. Escola. Superior de Agricultura*, universidade de sao paulao, Brasil, 116 pp.

*Pena, J. E., Waddil, V. H. and O' hair, S. K., 1984, Mites attacking Cassava in Southern Florida: damage descriptions and density estamate methods. *Fla. Ent.*, **67** (1) : 141-146.

Perring, T. M., Farrar, C. A. and Royalty, R. N. 1987. Intraplant distribution and sampling of spider mites (Acari : Tetranychidae) on cantaloupe. *J. Econ. Entomol.*, **80** (1): 96-101.

Pillai, S. V. and Jolly, M. S., 1986. Studies on the population build up and control measures of the red spidermite, *Tetranychus equatorius* (Mc Gr.). *Indian J. Seri.*, **25**(1) : 15-20.

Plaut, H. N., 1965. On the phenology and control value of *Stethorus punctillum* Weise as a predator of *Tetranychus cinnabarinus* Boisd. in Israel. *Entomophaga* **10** : 133-137.

*Poe, S.L., Shih, C.I. and Overman, A.J., 1976. Integrated tactics for management of spider mite population on florida strawberries. *Proc. Flo. State Hort. Soc.*, **89 :** 147-148.

Puttarudraiah, M., 1947. A note on the occurrence of the mite *Paratetranychus indicus* (H.) on jowar (*Andropogon sorghum*) and its predators in Mysore. *Curr. Sci.*, **16** (2): 60-61.

Quayle, J. H., 1913. Some natural enemies of spider mites. *J. Econ. Entomol.*, **6**(1): 85-88.

Radzivskaya, S., 1931. *Styethorus punctillum.* A destroyer of the red spiders, *Zakhlapkor Nezavisim.* No. 6-7 : 75-81.

Rai, A. B., Vora, V. T. and Patel, C. B., 1995. Investigations on the integrated control of *Tetranychus urticae* (Acari : Tetranychidae) infesting brinjal in south Gujarat. *Vth National Symposium on Acarology Abstracts*, Bangalore, India, September 20-22, 1995, Abst, No. 113.

Ramesh Vaidya., 1999. Management of *Tetranychus urticae* Koch (Acari : Tetranychidae) on rose in polyhouse conditions using *Amblyseius longispinosus* (Evans) (Acari : Phytoseiidae) M. Sc. (Agri). Thesis. Dept. of Entomology, University of Agricultural Sciences, Bangalore.

Rani, B.J., 1997. Eco-friendly approaches for management of red spider mites on carnation. *Paper presented at seminar "Flora '97"*, Bangalore, India, October 3-5, 1997, Abst. No. 1-10.

*Raworth, D. A., 1989. Towards the establishment of an economic threshold for two spotted spider mite *Tetranychus urticae* (Acari : Tetranychidae) on raspberry *Rubus idaeus*. *Acta Hort.*, **262** : 223-226.

Ragupahty, A. and Palanisamy, G. A., 1972. Note on the control of the red spider mite *Tetranychus telarius* on three field bean varieties. *Madras Agric. J.*, **59** :652-659.

Robinson, A.G., 1952. Annotated list of predators of tetranychid mites in Manitoba. *82 nd Ann. Rept. Ent. Soc.*, Ontarip. 1951, pp. 32-37.

Rodriguez, J. G., Reicosky, D. A. and Paterson, C. G., 1983. Soybean and mite interaction : Effects of cultivar and plant growth stage. *J. Kans. Ent.*, **56** (3) : 320-326.

Sachs, Y., Nakash, J., Swirski, E., Wyoski, M., Izhar, Y. and Amitai, S., 1983. Biological control of the caramine spider mite, *Tetranychus cinnabarinus* by the predacious mite *Phytoseiulus persimilis*. *Phytoparasitica* **11**: 133-134.

Sagar, P., 1978. Control of *Tetranychus cinnabarinus* infesting sponge gaurd. *Acarology Newsl.*, 6. pp. 8.

Samilanick, J. M. and Zalom, F. G., 1983. Eriophyid mites in relation to Kentucky blue grass seed production. *Entomol. Expt. Appl.*, **33** (1) ; 31-34.

Sanderson, J. P. and Zhang, Z. O., 1995. Dispersion, sampling and potential for integrated control of two spotted spider mite (Acari : Tetranychidae) on green house roses. *J. Econ. Entomol.*, **88**(2): 343-351.

Schweissing, F. G., 1973. Approaches to the management of the Bank's grass mite on corn. *Progress report.*, 73-141. Colarado state Univ. Fort, Callius, 3 pp.

Scopes, N. E. A and Stacey, D. L., 1977. Integrated pest control on Chrysanthemum and other flower crops. *Sci. Hortic.*, **31** :48-53.

Sharma, H. S. and Padey, Y. D., 1981. Seasonal incidence of *Tetranychus* sp. on four improved varieties of brinjal. In. : Channabasavanna, G. P., Mallik. B. and

Ghorpade, K. D. (ed.), *Contributions to Acarology in India*. Acarological Society of India. pp. 46.

Shibao, M., Negroro, M. amd Tanaka, H., 1995. Control of Kanzava spider mite, *Tetranychus kanzawai* Kishida on strawberry by *Phytoseiulus persimilis* Athias-Henriot and effect of smoking agents on both species. *Proceedings of the Kansai plant protection Society*, **37** :5-8.

Siharude, A. M., 1962 *Stethorus punctillum* as a natural enemy of red spider. *Aubtrtopiki kultary.*, **3** :64 -68.

Simmonds, S. P., 1971. Observations of the possible control of *Tetranychus urticae* on strawberries by *Phytoseiulus persimilis*. *Plant Pathol.*, **20** :117-119.

Smith, J. C. and Mozingo, R. W., 1983. Effect of two spotted spider mites (Acari : Tetranychidae) on large seeded virginia type peanuts. *J. Econ. Entomol.*, **76** (6) : 1315-1319.

Smith, J. C. and Mozingo, R. W., 1983. Effect of two spotted spider mites (Acari : Tetranychidae) on large seeded Virginia type peanuts. *J. Econ. Ent.*, **76** (6) : 1315-1319.

Solomon, M. A., 1949. The natural control of animal populations. *J.Ann. Ecol.*, **18** : 1-35.

Southwood. T. R. E., 1978. *Ecological methods*. Methuen and Co. Ltd., London, 216 p.

Steinberg, S. and Cohen, M., 1992. Biological control of two spotted spider mite (*Tetranychus urticae*) in apple orchards by inundative release of the predatory mite *Phytoseiulus persimilis*, a feasibility study. *Phytoparasitica*, **20** :37-44.

*Stenseth, C., 1988. Biological control of the green house spider mite on ornamental plants in the green house. *Garteneryrket.*, **78** (12) :383-385.

Strong, W. B. and Croft, B. A., 1995. Inoculative release of phytoseiid mites (Acarina : Phytoseiidae) into the rapidly expanding canopy of hops for control of *Tetranychus urticae* (Acarina : Tetranychidae). *Environ. Entomol.*, **24** (2) : 446-453.

Sudharma, K., Nair, G. M. and Kuriyan, K. J., 1995. Phytophagous mites on ornamental plant-occurrence and seasonal incidence in Kerala. *V National Symposium on Acarology Abstracts*, Bangalore, India, September 20-25, 1995, Abst. No. 13.

Tanigoshi, L. K. and Mcmurtry, J. A., 1977. The bionomics of predation of *Stethorus picipes* (Coleoptera : Coccinellidae) and *Typhlodromus floridanus* on the prey *Oligonychus punicae* (Acarina : Phytoseiidae, Tetranychidae)., *Hilgardia*, **45** (8) : 237-288.

Trichilo, P.J., Wilson, L. T. and Gonzaler, D., 1990. Relative abundance of three species of spider mites (Acari : Tetranychidae) on cotton, as influenced by the pesticides and time of establishment. *J. Econ. Entomol.,* **83** (4): 1604-1611.

*Untersteinhofer, G., 1954. Freilandver suche mit " systox" zur Bekampfung der obstbaum Spinne Milbe, *Paratetranychus pilosus. Can. Et. Fans. Hofchenbe. Bayer Pflschutz. Nachr.,* :7 :67-77.

Vacante, V., 1985. The current state of control of phytophagous mites in protected crops in Sicily. *Bulletin SROP.,* **8** (1) : 43-50.

Van de vrie, M., 1956. Over de invtoed van spintaansting op de op brengst engroei van vruchtbomen. *Tijdschr. Plziekt.,* **62** : 243-257.

Van de Vrie, M., 1985. Control of Tetranychidae in crops. *In: W. Helle and M.W. Sabelis* (Eds.) *spider mites, their biology, natural enemies and control.* Vol. **1B**, Elsevier, Amsterdam, Netherlands. pp. 273-283.

Vilajeliu, M. and Vilarnau, A., 1992. Feasibility of summer releasess of beneficial mites of the family Phytoseiidae to promote biological control of European red mite *Panonychus ulmi* in commercial apple orchards in Girana, Spain, *Boletin-de-Sandad Vegetalplagas,* **18** (1) :123-132.

Vilajeliu, M., Bosch, D., Lloret, P. L., Sarasua, M. J., Comelles, J. C. and Avilla J., 1994. Biological control of *Panonychus ulmi* (Koch) by Phytoseiid mites in IPM apple orchards in California. *Boletin de Sanidad Vegetalphagas*, **20** (1) : 173-185.

Weismann, R., 1968. Unter suchungen uber die var dauuny svorgange bei dei gerneinen sp innmibe *Tetranychus urticae* Koch. *Z. Angew. Ent .*, **61** : 457-465.

Welter, S. C., Barnes, M. M., Ting, I. P. and Hayashi, J. T., 1984. Impact of various levels of late-season spider mite (Acari : Tetranychidae) feeding damage on Almond growth and yield. *Environ. Entomol.*, **13** (1) : 52-55.

WenTailee and Kang-chenlo., 1989. Integrated control of two spotted spider mites on strawberry in Taiwan. *Chin. J. Entomol.* Spec. Publ., **2**(3) :125-137.

Wilson, L. T., Gonzalez. D., leigh. T. F., Maggi, V., Foristecere, C. and Goodell, P., 1983. Within plant distribution of spider mites (Acari : Tetranychidae) on cotton developing a implementable monitoring programme. *Environ. Entomol.*, **12** (1) : 128-134.

*Wood, L., Rawoth, D. A. and Mackuer, M., 1994. Biological control of the two spotted spider mite in raspberries with the predator mite, *Phytoseiulus persimilis. J. Entomol. Soc. British* (Colombia), **91**: 59-62.

Workman, p. J. and Martin. N. A., 1985. Integrated mite control. *New Zealand Commercial Grower*, **40** (7) : pp 44.

Wyman, J. A., Oatman, E. R. and Voth, V., 1979. Effect of varying two spotted spider mite infestation levels on strawberry yield. *J. Econ. Ent.*, **72** (5) : 747-753.

*Yaninek, J. S., Megevand, B., Moraes, G. J., DeBakker, F., Braun, A. and Herren, H. R., 1991. Establishment of Neotropical predator *Amblyseius idaeus* (Acari : Phytoseiidae) in Benin, West Africa. *Bio-control Science and Technology*, **1**(4) :323-330.

Zamora, J. E. G., Mari, F. G., Ribes, A., Saques, J., Masidello, L. and Orenga, S., 1993. Binomial and sequential sampling programmes for *Tetranychus urticae* Koch (Acari : Tetranychidae) and *Amblyseius californicus* (McGregor) (Acari : phytoseiidae) on Strawberries. *Boletin de Sanidad Vegetalplagus*, **119**(4): 559-586.

Zhang, Z. Q. and Sanderson, J. P., 1995. Two spotted spider mite (Acari : Tetranychidae) and *Phytoseiulus persimilis* (Acari : Phytoseiidae) on green house roses : Spatial distribution and predator efficacy. *J. Econ. Entomol.* **88**(2): 352-357.

Zwick, R. W., Fields, G. J. and Mellenthin, W. M., 1976. Effects of mite population density on 'Newtown' and golden delicious apple tree performance. *J. Am. Soc. Hort. Sci.,* **101** (2): 123-125.

* Original not seen