DISTRIBUTION OF COCONUT LACEWING BUG *Stephanitis typicus* Distant AND ITS NATURAL ENEMY COMPLEX AND ASSESSMENT OF BIOCONTROL POTENTIAL OF THE MAJOR NATURAL ENEMIES

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

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DECLARATION

I hereby declare that the thesis entitled **"Distribution of Coconut Lacewing Bug *Stephanitis typicus* Distant and Its Natural Enemy Complex and Assessment of Biocontrol Potential of the Major Natural Enemies"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that the thesis entitled **"Distribution of Coconut Lacewing Bug *Stephanitis typicus* Distant and Its Natural Enemy Complex and Assessment of Biocontrol Potential of the Major Natural Enemies"** is a record of research work done independently by **Mr. Unnimon, N.K.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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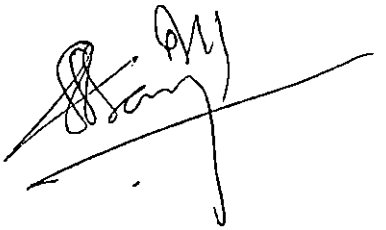

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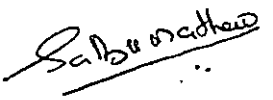

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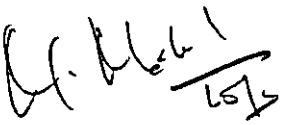

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Introduction

INTRODUCTION

Stephanitis typicus (Distant), the lacewing bug of coconut has been reported as a foliar pest of 16 different plants belonging to 13 genera under 8 families. In India it was first reported on coconut by Fletcher (1914). As a pest of coconut, it has only minor importance. But it is important as a suspected vector of the dreaded root (wilt) disease of coconut in Kerala (Joseph *et al.*, 1972); Mathen *et al.*, 1987).

S. typicus needs a sizeable population for spreading the disease. A positive correlation between the vector abundance and disease intensity was reported by Mathen (1985).

Hence, as a long term strategy, it is important to keep the vector under minimal population by permanent methods. Since coconut is a perennial tree which limits insecticidal choices, and also due to the limitations in the efficacy of insecticidal pest suppression, in the context of coconut pest management, biological control is of utmost importance.

In this method, management is done by the introduction and encouragement of natural enemies. Thus, it is vital to

identify the natural enemies of S. typicus and their predatory and parasitic potential. Also, for effective biological suppression of the pest, it is essential to understand the population abundance of the pest and also its distribution. Hence the present investigation was carried out with the following objectives.

1. Survey and spatial distribution of S. typicus and its natural enemies, to study the population abundance of the pest and natural enemies.

2. Rearing of S. typicus on different host plants to maintain the laboratory culture, and,

3. Determine the predatory/parasitic potential of the natural enemies.

Review of Literature

REVIEW OF LITERATURE

2.1 Biology and pest status

Stephanitis typicus (Dist) was first recorded as a pest of crop plant from Ceylon by Distant (1903) on banana. He observed the attack of the pest by puncturing the leaves of cardamom, heydychium and allied scitaminae. Distant (1910) noticed the occurrence of S. typicus (Dist) in Manila ... Philippines. Fletcher (1914) reported the tingid feeding on turmeric and banana in South India and later (Fletcher, 1920) in Bengal. Corbett (1928) observed the attack of S. typicus (Dist) on banana and on coconut in Malaya (Corbett, 1932).

The bug was observed for the first time in Canton by Hoffmann (1935). According to him the adults and nymphs remained together on the under surface of the leaf, the adults laid about 60 eggs and the eggs were found inserted in the tissues on the under side of the leaf. He opined that the tingid has several generations in an year and the second of which is completed by the middle of July. Takahashi (1936) noticed the occurrence and attack of the lace wing bug in Formosa, China, India and later Ramakrishna Ayyar (1942) reported the same on banana plants in the Malabar Coasts of India. Nerula (1955) summarised S. typicus (Dist) as a minor

pest of coconut, causing only negligible damage and often found on tender leaves.

Mathen (1960) described the detailed biology of the pest. According to him the eggs were laid singly on the under surface, inserted into the leaf tissue and was covered over by a protective operculum. The incubation period under laboratory conditions was 12 days on an average. He summarised that the nymph moults five times before it metamorphoses into the imago and the male and female live for a maximum period of 25 and 21 days respectively. He concluded that the fecundity of the tingid is not high and the average number of eggs laid by a single female does not exceed 4 per day.

Koyusiu and Chuyau (1966) reported that the tingid had six generations in an year, each completed within 30 to 45 days. They noticed the over wintering of S. typicus (Dist) in the egg stage. According to Cheng (1967), there were nine generations of the pest in an year, with the average incubation period in summer and winter, length of the nymphal stage and complete life cycle and female life cycle in summer and winter as 11.92, 32.10, 17.69, 37.82, 7.1 and 36.8 days respectively. He described that the average number of eggs laid was 36.8 per female and about 69.05 per cent of the hatched nymphs reached to adult stage.

Chari and Patel (1973) reported the tingid S. typicus (Dist) for the first time in Gujarat. The damage caused by the tingid on turmeric was reported by Butani (1985). According to Tigvattanont (1990) the tingids laid eggs singly or in groups near the mid rib of the leaf. He stated that there were 5 nymphal instars and the egg and nymphal periods averaged 10.02 and 10.41 days. The adult life span noticed by him was, an average of 39.80 days for males and 26.07 days for females and the eggs laid per female averaged 190.07.

2.2 Symptoms of attack

Puncturing of the leaves of cardamom, Heydychium and allied Scitaminae were reported by Distant (1903). Mathen (1960) reported that the insects feed from the under surface of the leaflet causing yellow spots on the upper surface of the leaf. When they were very close, the entire leaf surface may appear in yellow patches. Cheng (1967) noticed the feeding habit of the tingid and reported that the adults and nymphs of this insect feed on the sap from the lower surface of the leaves, causing greyish yellow blotches and retardation of the plant growth.

The nature and extent of damage caused by S. typicus (Dist) to coconut by their feeding was studied by Mathen et al. (1979). They pointed out that the adult and nymphs of

all stages feed from the lower surface of coconut pinnae, leaving permanent chlorotic spots on the adaxial surface. These yellow scars vary from small pin pricks to large coalesced patches with an average area of 0.112 mm^2 under laboratory conditions. According to them, a single adult can make such scars by feeding for 24 hours and destroys 0.44μg per gram fresh weight of the leaf. Tigvaltnanont (1990) reported that both the adults and nymphs were sucking the cell sap of banana from the lower surface of the leaves, causing the minute white spots on the upper surface and yellowing of lower surface and ultimately the withering of leaves.

2.3 Pattern of distribution and seasonal abundance

Cheng (1967) noticed that the population of S. typicus (Dist) was larger and denser in Banana plantations sheltered from wind. The adults were most active on the uppermost leaves, but most of the nymphs were found on middle leaves. He described that, during the dry season (September-May) populations were large and during rainy season they were reduced. According to him, low level of population was noticed throughout the summer and all stages of the pest were visible in the winter.

Mathen et al. (1967) observed that the population of S. typicus (Dist) was maximum in March, April and May in the

field. They summarised that the pest occurs in maximum numbers in April and subsides in July, from August onwards there is again a gradual increase in population and showed a rise in October. They opined that the abundance of population is negatively related to rainfall and humidity, while with temperature and sunshine the relation is positive.

Population studies conducted by Mathen et al. (1969) revealed that the tingid was present in increasing density from the outer to the inner leaves of coconut and that it was more numerous on the central leaflets than those at either ends of the leaf. Mathen (1985) observed a correlation between S. typicus (Dist) abundance and an ascending order of fresh incidence of root (wilt) disease in coconut palms. According to Mathen (1986), the tingid populations were generally greater on diseased trees than in the healthy ones. He observed about 4 times greater number of adults and nymphs on diseased coconuts than on healthy ones.

The seasonal abundance of S. typicus (Dist) was studied by Patil et al. (1988) on turmeric and ginger. They noticed that the pest appeared in the field in the second fortnight of September and the population of the Tingid reached maximum in November.

Pillai et al. (1991) studied the population of the lacewing bug S. typicus (Dist) and its mirid predator Stethoconus praefectus (Dist) by taking observations at weekly intervals. A higher population density of the pest was noticed in the field in January, June, October and November.

2.4 Transmission of the disease

Nagaraj and Menon (1956) from their transmission studies noticed that the lacewing bug S. typicus (Dist) transmitted the root (wilt) disease from an affected plant to a healthy plant. According to them the bugs collected from the diseased palms, when allowed to feed on healthy palms for a period of seven days produced the symptoms of disease in healthy plants. Shanta et al. (1960), conducted inoculation studies using the lace wing bug and described the vector role of the insect for the coconut root (wilt) disease. It was observed that the percentage of infection was 20 to 60 per cent higher in inoculated plants than the control palms. The experiments conducted using cowpea as indicator plant by Shanta and Menon (1960), proved that the lace wing bug can transmit the disease symptoms to the indicator plant. They concluded that the tingid after feeding 24 hr on diseased coconut, can induce disease symptoms on indicator plants.

Holmes et al. (1965) opined that S. typicus (Dist), the vector of coconut root (wilt) disease is likely to move from infected palms to healthy ones when the former are cut down, unless preventive measures are taken. Joseph et al. (1972) described that even a single tingid can transmit the disease from a diseased plant to a healthy plant. They summarised that it needs about two hours of acquisition feeding and 16 hour of inoculation feeding for the successful transmission of the pathogen to the new plant. They found that infectivity was lost during the lapse feeding. Mathen et al. (1979) proved the vector role of S. typicus (Dist) by conducting inoculation experiments of palms in the field as well as seedlings under insect proof greenhouse conditions. A correlation between yield and disease index were worked out for 100 palms of CPCRI by Pillai et al. (1982) with a significant higher population of S. typicus in diseased palms as compared to the healthy ones.

Experimental transmission studies were made by Mathen and Rajan (1983) using leafhoppers, planthoppers and lacewing bugs on coconut. They observed a direct linear correlation between numerical abundance of lacebugs and fresh incidence of root (wilt) disease. Solomon et al. (1984) studied the vector role of lacewing bug using electron microscope. They failed to observe the MLOs in salivary glands of bugs collected from

disease free area. Mathen (1985) studied the correlation between the number of lacebugs on apparently healthy coconut palms in root (wilt) disease prevalent tract and incidence of the disease on the same lot of palms in subsequent years. The results showed an ascending order of fresh incidence of root (wilt) with increase in abundance of the insect. He attributed it to an indirect role of the insect in the transmission of the pathogen.

The comparative abundance of tingid population was studied by Mathen (1986) on healthy and disease affected palms. Both diseased and disease free areas were selected for the study and it was noticed that the tingid population was generally greater on diseased trees than on healthy ones. Soloman et al. (1986) from their electron microscopic studies, reported that the nymphs failed to transmit the pathogen from a diseased plant to the healthy plants. Third instar nymphs of lacebugs were collected by them and allowed to feed on diseased palms for five days. These nymphs were recaptured and maintained on leaflets of symptomless palms. Electron microscopic examination of the adults failed to show the MLO's in the salivary glands or other tissues of the bug. They concluded that the nymphs fails to acquire the MLO's and even if they do, the organisms are trans-stadialy carried over to the imago.

Electron microscopic studies were conducted by Mathen et al. (1987), and MLO's were isolated from the salivary glands and brains of lacewing bugs, exposed to infected palms for two to three weeks previously. According to them, these MLO's provide evidence of the role of these insects in transmitting the disease. Mathen et al. (1988) reported the vector nature of the tingid S. typicus (Dist) from the stylet course study of the insect in the laboratory. He stated that the insect could acquire the phloem bound Mycoplasma like organisms during feeding, because the stylet tip of the insect is terminated into the phloem during the process of feeding.

2.5 Bio-control agents

Hoffmann (1935) reported that a capsid was found attacking the nymphs of the tingid S. typicus (Dist). According to him the adult tingids were not attacked by the capsid. Cheng (1967) summarised the different Stethoconus spp. which preys on the nymphs and adults of the tingid. They were found throughout the year except during December and January. He noticed that the adult female mirid predator lays an average of 34 eggs and the life cycle lasted for 8-18 days. The predacious nature of Stethoconus praefectus (Dist) was reported by Mathen et al. (1967). They observed it feeding on the nymphs and adults of the tingid. Laboratory studies were made by Mathen et al. (1970) on S. praefectus (Dist) and

reported the life history and predacious nature of the mirid. They concluded that the life cycle occupied a period of 16.6 ± 0.61 days with an incubation period of 7.1 ± 0.53 and total nymphal period of 9.5 ± 0.95 days. According to them, there is a slight preponderance of the females in the field.

The biology and the predatory potential of the mirid S. praefectus (Dist) were studied in detail by Mathen and Kurian (1972). They observed five nymphal instars and the life cycle averaged 16.6 days. According to them, the males lived for 12 to 20 days and the females for 12 to 45 days. They stated that, the number of eggs laid by the female averaged 2.1 per day and summarised that the number of S. typicus devoured by nymphs of the predator in the course of its development averaged 62.3 and that adults consumed an average of 5.2 hosts per day.

As a natural enemy of S. typicus (Dist), the mirid S. praefactus was reported by Vadivelu (1975). Pillai (1985) studied the biological suppression of the tingid bug using S. praefectus (Dist) and made attempts to standardise a technique for the lab culturing of the mirid predator. They collected a hemerobid predator from Minicoy and Lakshadeep and studied the feeding nature of it. The rate of prey consumption observed was 6 adults/9 nymphs of S. typicus per predator per day.

Pillai et al. (1990) studied the life cycle of the mirid predator in the laboratory. They observed that the average number of eggs laid by the female was 5.6 and the hatching percentage w very poor. An anthocorid bug was also recorded as a predator S. typicus in the field.

The population of lace bug and its mirid predator S. praefectus (Dist) were recorded at weekly intervals by Pillai et al. (1991). In their studies on breeding of the mirid predators in laboratory on coconut seedlings, turmeric, wild species of curcuma and arrowroot, they observed egg laying of the predator in all the plants. The pre-release of S. typicus on the host plants, a few days prior to the release of the predator resulted in better survival of the first instar nymphs of the predator.

Pillai and Sathiamma (1986) reported one chrysopid namely Ancylopteryx octopunctata as one of the natural enemies of the tingid other than S. praefectus (Dist). Attempts on standardising a technique for culturing the mirid predator in the laboratory were made by Pillai (1987).

2.6 Microbes

Pillai (1985) isolated a fungal pathogen from field collected tingids. In pathogenecity tests he observed that the treated group of adult bugs developed mycosis and died

Materials and Methods

MATERIALS AND METHODS

The present study aimed at assessing the spatial distribution of S. typicus and its natural enemies and determining its predatory/parasitic potential was conducted at different locations in Trichur, Ernakulam, Kottayam and Alappuzha districts. In each district, 3 locations were chosen, such that the survey covered 12 locations in 4 southern districts of the state in which the incidence of the root (wilt) disease was very prevalent. The observations were taken from November 1991 to October 1992 at monthly intervals. A total of twelve observations were made from each location. The details of the selection of locations, various observations taken and the statistical tools used are given in this chapter.

3.1 Selection of locations for the population assessment of S. typicus and its natural enemies

An initial survey was conducted to identify the suitable locations for the study. Plantations of the coconut root (wilt) disease prone areas of four districts of Kerala were selected for the study. The locations selected from the four districts are given in the Table 1. Three locations were selected from each district and a total of 12 localities were

Table 1. Locations selected for assessing the population of S. typicus and its natural enemies

No.	District	Location		
		1	2	3
1	Trichur	Vellanikkara	Irinjalakkuda	Chalakkad
2	Ernakulam	Vyttila	Mulanthuruthy	Muvattupuzha
3	Kottayam	Kozha	Kumarakom	Thodupuzha
4.	Alleppy	Cherthala	Kayamkulam	Mavelikkara

covered from the four districts during the entire period of study.

3.2 Selection of palms

Coconut palms upto seven years in age were selected for the study. From each identified location, three palms were selected for taking observations. The observations were made from three leaves each at the upper, middle and bottom whorls of each palm. From each of the selected leaves, assessment of population was made by counting the number of S. typicus and its natural enemies present at five pairs (on opposite sides) of leaflets in the top, middle and basal region of the leaves. Thus, in each leaf, 10 leaflets were surveyed and from each level, it made 30 leaflets. Since there were three levels, i.e., top, middle and bottom a total of 90 leaflets were surveyed from each plant. This also meant that 270 leaflets were surveyed from each location every month. The counts of S. typicus included the total population of S. typicus adults.

3.3 Observations

Monthly observations were taken from the selected palms in the identified locations. Nine observations were taken from each palm per month, so that a total of 27 observations were taken from each locality. The time gap

between two observations was 30 days. Thus, 12 observations were taken from each locality during the period of study.

3.4 Maintenance of S. typicus in the laboratory

Insects collected from the field were brought to the laboratory perforated polythene bags and reared in the laboratory to maintain a stock culture for further studies. For this, bits of coconut leaflets were used. The healthy coconut leaflets collected from the field were cut into 15-20 cm height and the cut end of the leaflets were dipped in water kept in a 250 ml beaker. The nymphs and adults of field collected S. typicus were transferred carefully into the cut leaflets and the whole arrangement covered with a netted cage. Periodical removal of the used up coconut leaflets, once in a week was necessary to maintain the culture properly. Similarly the insect culture was maintained on banana and colocasia leaves.

Culture of S. typicus was also maintained in glasshouse on coconut seedlings, potted turmeric plants and in potted curcuma plants.

3.5 Predatory/parasitic potential

The field collected natural enemies were taken to the laboratory and predatory/parasitic potential of the natural

enemies were studied by offering them host insects. For this, the natural enemies collected from field were sorted out in the laboratory. They were then kept singly in glass vials. Counted number of adults or nymphs of S. typicus offered to the natural enemies everyday. The observations were taken on the number of insects consumed by the natural enemies every day.

3.6 Rearing of Stethoconus praefectus (Dist). (Miridae)

S. praefectus (Dist) is an important predator of S. typicus. To find out the predatory potential of this natural enemy, it was necessary to maintain a stock culture of the predator in the laboratory.

Rearing of S. praefectus was done in coconut leaflets in the laboratory to determine its pedatory potential. The field collected insects were used for this. The insects were released on the healthy cut coconut leaflets of 10-15 cm size. The coconut leaflets were split through the midrib region. These splits were then placed in glass vials containing water. The base of the splits were fixed to the vial using cotton plug in glass vial. This arrangement was made to prevent the drying up of the leaf. Then the glass vials fitted with cut leaf split was placed in petri dishes and the whole set up was

covered with glass chimney, the top end of which was covered with muslin cloth.

The field collected adult insects were brought to the laboratory in polythene bags and transferred carefully into the cut coconut leaf splits through the bottom portion of the glass chimney by lifting it gently. Sufficient number of S. typicus were also supplied by the same way. This arrangement was kept undisturbed and S. praefectus adults were allowed to lay eggs in the cut leaflets. After the death of the released adult S. praefectus the leaflets were kept undisturbed and watched for the emergence of nymphs.

The newly emerged nymphs were also reared by the same way by supplying sufficient number of S. typicus nymphs and adults as feed.

3.7 Determination of predatory potential of S. praefectus

The newly emerged S. praefectus nymphs were transferred to the cut coconut leaflets of 10 cm height, placed in the glass vials. Counted number of S. typicus nymphs were supplied as feed every day. The number of host nymphs consumed everyday was noted. In the same way the predatory potential of the adult S. praefectus was also studied by supplying counted number of S. typicus adults and

nymphs at an interval of 24 hours. Observations were made daily.

3.8 Determination of the predatory potential of spiders

One of the major group of natural enemies of S. typicus other than S. praefectus was the different types of spiders. The field collected spiders were brought to the laboratory in polythene bags and the predatory potential was studied by supplying counted number of S. typicus, to the spiders kept in glass vials separately. Observations were made daily. The number of prey consumed daily was recorded by taking observations every 24 hours.

3.9 Observations on parasites and parasitic potential

During the period of the study, the populations of S. typicus were surveyed for the presence of parasites or parasitised host insects.

To study the parasite emergence, dead and weaker insects collected from the field were placed in test tubes plugged with cotton and observed for the emergence of parasites/parasatoids.

3.10 Correlation of population of S. typicus and its natural enemies with weather factors

The influence of weather factors on the population of S. typicus and also its natural enemies were worked out and the correlation matrix worked out as per the procedure given by Panse and Sukhatme (1985). For this purpose rainfall, relative humidity at 8 am and the maximum/minimum temperature were correlated with the population of S. typicus and its natural enemies. The effect of host population on the natural enemy build up was also correlated.

Results

RESULTS

A survey was conducted in four districts of Kerala viz., Trichur, Ernakulam, Kottayam and Alappuzha to determine the spatial distribution of S. typicus and its natural enemies. The major predators were identified and the predatory potential of these predators were also recorded. The observations taken on these aspects are presented below.

4.1 Spatial distribution of S. typicus in Trichur district

The observations recorded are given in Table 2. The population showed a low level from November to December, Then it started increasing in January and reached its maximum in April (43 adults/90 leaflets). From May onwards it started decreasing and reached minimum in June-July (5 adults/90 leaflets). A second rise in population was noticed from August to October.

4.1.1 Spatial distribution of S. typicus at Vellanikkara

Population was maximum in April-May, after which it started decreasing and reached the lowest in June-July. Again a second increase in population was noticed from August onwards and reached the second maximum in October. From

November to December the population again decreased and then slightly increased in January to February (Table 2).

4.1.2 Spatial distribution of S. typicus at Irinjalakuda

A low level of population was noticed in November-December. A rise in population was noticed from January onwards and reached its maximum in April. Then the population started declining and reached the minimum in June-July. From August onwards a slight increase in population was observed and the population showed a second part level in September and October (Table 2).

4.1.3 Spatial distribution of S. typicus at Chavakkad

The population was low in November-December. Then an increase was recorded from January to February. Again there was a slight decrease from February to March. It increased and reached the maximum in April. The population showed a decreasing tendency from April to June and reached the lowest level in July. There was a rise in population from August to October (Table 2).

4.2 Spatial distribution of S. typicus in Ernakulam district

Table 3 shows the observations recorded from Ernakulam district.

Table 2. Spatial distribution of S. typicus at different locations of Trichur district at monthly intervals

Month	Vellanikkara			Total	Irinjalakkuda			Total	Chavakkad			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	3^{a}	5^{c}	2^{b}	10^{E}	5^{b}	2^{d}	3^{c}	10^{E}	6^{c}	2^{d}	0^{a}	8^{A}	6.0
Dec.	2^{b}	3^{c}	1^{b}	6^{C}	4^{c}	1^{b}	0^{a}	5^{B}	1^{a}	0^{a}	2^{c}	3^{A}	4.6
Jan.	6^{a}	2^{a}	4^{a}	12^{A}	13^{c}	7^{b}	5^{b}	25^{B}	12^{b}	13^{c}	6^{c}	31^{C}	22.6
Feb.	11^{a}	2^{a}	3^{a}	16^{A}	22^{b}	16^{b}	11^{b}	49^{B}	24^{c}	25^{c}	15^{c}	64^{C}	43.0
Mar.	6^{a}	3^{a}	2^{a}	11^{A}	41^{c}	24^{c}	12^{b}	77^{C}	24^{b}	14^{b}	15^{c}	53^{B}	47.0
Apr	46^{a}	27^{a}	10^{d}	83^{A}	56^{c}	39^{c}	25^{c}	120^{C}	47^{b}	29^{b}	10^{d}	86^{B}	6.3
May	14^{a}	9^{a}	4^{a}	27^{A}	33^{c}	18^{c}	9^{c}	60^{C}	18^{b}	15^{b}	7^{b}	40^{B}	4[illegible].3
Jun	6^{d}	2^{c}	0^{a}	8^{C}	3^{a}	1^{d}	3^{c}	7^{A}	6^{d}	1^{d}	1^{b}	8^{E}	7.6
July	3^{d}	2^{c}	0^{a}	5^{D}	4^{c}	1^{d}	1^{e}	6^{C}	3^{d}	1^{d}	1^{e}	5^{D}	5.3
Aug.	7^{a}	2^{a}	2^{a}	11^{A}	15^{c}	12^{e}	7^{e}	34^{C}	14^{b}	12^{e}	7^{e}	33^{B}	26.0
Sep.	11^{a}	3^{a}	5^{a}	19^{A}	22^{c}	22^{c}	11^{b}	55^{C}	15^{b}	10^{b}	12^{c}	37^{B}	37.0
Oct.	18^{a}	15^{b}	6^{a}	39^{A}	25^{b}	15^{b}	12^{e}	52^{B}	27^{c}	15^{b}	12^{e}	54^{C}	48.3

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

Table 3. Spatial distribution of S. typicus at different locations of Ernakulam district at monthly intervals

Month	Vyttila			Total	Mulanthuruthy			Total	Muvattupuzha			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	5^{e}	2^{d}	0^{d}	7^{D}	2^{a}	4^{c}	4^{c}	10^{C}	5^{e}	2^{d}	0^{d}	7^{D}	8.0
Dec.	2^{b}	0^{a}	0^{d}	2^{A}	2^{b}	2^{d}	0^{d}	4^{B}	2^{b}	2^{e}	1^{a}	5^{C}	3.6
Jan.	12^{a}	9^{b}	4^{a}	25^{A}	14^{b}	8^{a}	5^{b}	27^{B}	18^{c}	10^{c}	6^{c}	34^{C}	28.0
Feb.	12^{b}	6^{a}	3^{b}	21^{A}	17^{c}	8^{b}	2^{a}	27^{C}	11^{a}	11^{c}	4^{c}	22^{B}	23.5
Mar.	17^{d}	15^{b}	8^{c}	40^{C}	17^{d}	17^{c}	3^{d}	37^{B}	19^{c}	12^{a}	3^{d}	34^{D}	37.0
Apr	53^{c}	34^{c}	16^{b}	103^{C}	45^{b}	25^{b}	27^{c}	97^{B}	30^{a}	22^{a}	14^{a}	66^{A}	88.6
May	29^{c}	9^{b}	4^{b}	42^{C}	18^{b}	6^{a}	5^{c}	39^{B}	15^{a}	10^{c}	2^{a}	27^{A}	108.0
Jun	3^{a}	0^{d}	3^{c}	6^{C}	4^{b}	0^{d}	1^{d}	5^{A}	5^{c}	1^{c}	1^{d}	7^{B}	6.0
July	4^{e}	0^{a}	0^{d}	4^{A}	4^{e}	1^{b}	1^{c}	6^{C}	3^{a}	2^{c}	0^{d}	5^{B}	5.0
Aug.	10^{b}	4^{a}	2^{b}	16^{D}	9^{a}	6^{b}	1^{a}	16^{D}	13^{c}	12^{c}	4^{c}	29^{C}	20.3
Sep.	12^{a}	6^{a}	3^{d}	21^{A}	18^{c}	9^{b}	6^{c}	33^{C}	16^{b}	10^{c}	3^{d}	29^{B}	27.6
Oct.	15^{a}	8^{a}	4^{a}	27^{A}	35^{c}	24^{c}	12^{c}	71^{C}	18^{b}	9^{b}	7^{b}	34^{B}	44.0

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

The trend was almost similar in Trichur district. Rise in population was noticed two times in an year. The first one was in February-May and the second one in September-October. The population was very low in the field during June-July and November-December.

4.2.1 Spatial distribution of S. typicus at Vyttila

A low level of population was observed in November-December. Then it increased in January. A slight decrease in population was recorded during February. From March onwards it increased and reached its maximum in April. From May the population of S. typicus declined and reached the lowest in June-July. A rise in population was again observed in August-September (Table 3).

4.2.2 Spatial distribution of S. typicus at Mulanthuruthy

A rise in population was seen two times in an year. One in March-April and the second one in September-October. In November-December the population was low. An increase in population was noticed in January. It was almost equal upto February. Then it increased and reached maximum in April. A low level of population was observed in June-July (Table 3).

4.2.3 Spatial distribution of S. typicus at Muvattupuzha

Increase in population was observed two times in an

year, one in March-April and the other in August-September. In November-December, the population was low. It started increasing in January. A slight decrease in population was observed in February. The lowest population was noticed in June-July. A second rise in population was observed from July onwards. The population was almost equal in August and September and an increase was recorded in October (Table 3).

4.3 Spatial distribution of S. typicus at Kottayam district

The observations recorded from Kottayam district are presented in Table 4.

In November-December the field population was low and slightly increased in January-February and reached its maximum in March-April. Then it started decreasing and was the lowest in June-July. A second peak was noticed in September-October.

4.3.1 Spatial distribution of S. typicus at Kozha

Population was low in November-December. From January onwards it started increasing and reached a maximum in April. A decrease in population from May with the lowest in June-July was noticed. Again a rise in population was recorded from August and reached the maximum of the second peak in October (Table 4).

Table 4. Spatial distribution of S. typicus at different locations of Kottayam district at monthly intervals

Month	Kozha			Total	Kumarakam			Total	Thodupuzha			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	5^{d}	2^{e}	1^{e}	9^{B}	6^{c}	2^{e}	0^{a}	10^{C}	5^{d}	1^{a}	1^{e}	7^{A}	8.6
Dec.	1^{a}	2^{b}	1^{b}	4^{B}	4^{c}	4^{c}	2^{c}	8^{C}	3^{b}	0^{a}	0^{a}	3^{A}	5.0
Jan.	14^{b}	4^{a}	5^{b}	23^{D}	16^{c}	12^{c}	6^{c}	34^{C}	11^{a}	8^{b}	4^{a}	23^{D}	26.6
Feb.	20^{c}	8^{d}	6^{b}	34^{B}	12^{d}	8^{d}	8^{c}	38^{C}	12^{d}	9^{c}	3^{a}	24^{A}	32.0
Mar.	39^{a}	25^{c}	11^{b}	75^{C}	40^{b}	21^{b}	7^{a}	68^{A}	41^{c}	15^{a}	14^{c}	70^{B}	76.3
Apr	57^{b}	17^{a}	17^{a}	91^{A}	67^{c}	41^{c}	31^{c}	139^{C}	48^{a}	28^{c}	18^{b}	94^{B}	95.3
May	29^{a}	18^{c}	6^{b}	53^{C}	30^{e}	15^{b}	4^{a}	49^{A}	30^{e}	12^{a}	10^{c}	52^{B}	51.3
Jun	5^{c}	1^{a}	2^{c}	8^{C}	3^{b}	3^{e}	1^{b}	7^{B}	2^{a}	3^{e}	0^{a}	5^{A}	6.6
July	4^{b}	2^{c}	1^{c}	7^{C}	4^{b}	1^{d}	0^{d}	5^{D}	4^{b}	1^{d}	0^{d}	5^{D}	5.6
Aug.	12^{c}	6^{b}	6^{a}	24^{C}	9^{b}	6^{b}	8^{c}	23^{B}	6^{a}	6^{b}	7^{b}	19^{A}	22.0
Sep.	18^{c}	16^{c}	7^{b}	41^{C}	15^{b}	8^{a}	8^{c}	31^{B}	14^{a}	9^{b}	4^{a}	27^{A}	33.0
Oct.	24^{d}	15^{b}	6^{d}	45^{B}	30^{c}	18^{c}	12^{c}	60^{C}	24^{d}	10^{a}	6^{d}	40^{A}	48.3

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

4.3.2 Spatial distribution of S. typicus at Kumarakom

Two peaks observed in population were in March-April and the other in September-October. In November-December, the population was low in the field. An increase was observed from January onwards and reached the maximum population in April. Then a decrease in population was observed in May and reached the lowest in June-July. Again the population increased from August to October.

4.3.3 Spatial distribution of S. typicus at Thodupuzha

The peaks of population observed were the same. The highest peak was in March-April and the second one in September-October. In November-December the level of population was low in the field. It started increasing in January and reacheed maximum in April. From May onwards it showed decreasing trend and reached the lowest level in June-July. Again an increase in population was recorded from August-October and started decreasing in November-December.

4.4 Spatial distribution of S. typicus in Alappuzha district

Table 5 shows the observations recorded from Alappuzha district. A stagnant stage in population was noticed in November-December and then showed an increasing trend from then on and reached the maximum in March-April. Minimum

Table 5. Spatial distribution of S. typicus at different locations of Alappuzha district at monthly intervals

Month	Cherthala			Total	Kayamkulam			Total	Mavelikkara			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	8^{c}	2^{b}	0^{a}	10^{B}	7^{b}	3^{c}	1^{e}	11^{C}	5^{a}	1^{a}	1^{e}	7^{A}	9.3
Dec.	4^{b}	1^{a}	0^{d}	5^{D}	5^{c}	2^{d}	0^{d}	7^{C}	2^{a}	2^{d}	1^{c}	5^{D}	5.6
Jan.	36^{b}	29^{c}	13^{c}	78^{C}	41^{c}	20^{b}	7^{b}	68^{B}	32^{a}	13^{a}	5^{a}	50^{A}	65.3
Feb.	51^{d}	37^{b}	10^{e}	98^{B}	51^{d}	42^{c}	7^{a}	100^{C}	49^{a}	33^{a}	10^{e}	92^{A}	96.6
Mar.	59^{b}	45^{c}	22^{c}	126^{C}	62^{c}	42^{a}	16^{b}	120^{B}	52^{a}	43^{b}	11^{a}	106^{A}	117.5
Apr	46^{a}	46^{e}	36^{b}	128^{A}	58^{c}	43^{a}	31^{a}	132^{B}	51^{b}	46^{e}	37^{c}	134^{C}	131.3
May	47^{b}	45^{c}	12^{d}	109^{C}	49^{c}	44^{b}	12^{d}	105^{B}	42^{a}	37^{a}	6^{a}	85^{A}	99.6
Jun	5^{a}	4^{b}	1^{d}	10^{A}	6^{d}	4^{b}	1^{d}	11^{B}	6^{d}	4^{b}	2^{c}	12^{C}	9.6
July	5^{b}	1^{a}	0^{d}	6^{A}	5^{b}	3^{c}	2^{c}	10^{C}	5^{b}	2^{b}	0^{d}	7^{B}	28.3
Aug.	37^{c}	24^{e}	7^{c}	68^{C}	21^{a}	21^{a}	6^{d}	48^{A}	23^{b}	24^{e}	6^{d}	53^{B}	56.3
Sep.	51^{c}	36^{c}	9^{b}	96^{C}	42^{a}	23^{a}	9^{b}	74^{A}	43^{b}	30^{b}	9^{b}	82^{B}	84.0
Oct.	47^{c}	31^{c}	12^{a}	90^{C}	27^{a}	18^{a}	15^{b}	60^{A}	42^{b}	24^{b}	18^{c}	84^{B}	78.0

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

population in the field was noticed in June-July. Here also a second rise in population was recorded in September-October.

4.4.1 Spatial distribution of S. typicus at Cherthala

A low level of population was observed in November-December. Increase in population was observed in January. Population was highest in March and April. From May onwards a decreasing tendency was recorded and in JUne-July the population was comparatively low. It started increasing again in August and September.

4.4.2 Spatial distribution of S. typicus at Kayamkulam

Two peaks of pest populations were observed in an year, one in March-April and the other in September-October. A low level population was observed in November-December. An increase was recorded in January and reached the peak in April. It started decreasing from May. In the months of June-July the population was very low in the field. An increase in population was noticed from August onwards and reached maximum of the second peak in September. From October onwards decrease in population was recorded and reached the lowest level population in November-December.

4.4.3 Spatial distribution of S. typicus at Mavelikkara

The population showed the same trend. Maximum field

population was recorded in April. In November-December the population was low. It reached a maximum in April. From May onwards it started decreasing and the population was very low in June-July. Again it started increasing in August and reached the maximum of the second peak in October.

4.5 Spatial distribution of natural enemies in Trichur district

The distribution of natural enemies recorded are summarised in Table 6.

The population of natural enemies was found to remain constant throughout the year. There was no significant difference between the populations of different locations of Trichur. Only a slight increase in population was noticed in February, March, September and November. In December, the field population of natural enemies were observed to be more than that of S. typicus. In July it was almost equal.

4.5.1 Spatial distribution of natural enemies at Vellanikkara

The population remained in the same level throughout the year. In July it was found equal to that of pest population.

Table 6. Spatial distribution of natural enemies of S. typicus at different locations of Trichur district at monthly intervals

Month	Vellanikkara			Total	Irinjalakkuda			Total	Chavakkad			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	3^{e}	2^{b}	2^{d}	7^{B}	3^{e}	$2(1)^{*b}$	$2(1)^{*d}$	7^{B}	2^{a}	$2(1)^{*b}$	3^{c}	7^{B}	7.0
Dec.	2^{d}	1^{a}	2^{b}	5^{A}	2^{d}	$2(1)^{*e}$	2^{b}	6^{B}	3^{c}	2^{e}	2^{b}	7^{C}	6.0
Jan.	2^{b}	2^{e}	2^{e}	6^{E}	2^{b}	2^{e}	$2(1)^{*e}$	6^{E}	2^{*b}	1^{a}	1^{*a}	4^{A}	5.3
Feb.	3^{c}	1^{b}	3^{b}	7^{C}	2^{d}	1^{b}	$3(2)^{*b}$	6^{D}	2^{d}	1^{*b}	$3(2)^{*b}$	6^{D}	6.3
Mar.	1^{b}	1^{a}	3^{b}	5^{A}	1^{b}	$2(1)^{*b}$	$3(2)^{*b}$	6^{B}	1^{b}	$3(1)^{*c}$	$3(2)^{*b}$	7^{C}	6.0
Apr	2^{a}	1^{d}	1^{b}	4^{A}	3^{*e}	3^{c}	0^{a}	6^{B}	$3(2)^{*c}$	1^{d}	3^{c}	7^{C}	5.6
May	2^{b}	3^{c}	1^{a}	6^{B}	$4(3)^{*c}$	1^{a}	2^{e}	7^{C}	1^{a}	2^{b}	2^{e}	5^{A}	6.0
Jun	3^{b}	0^{a}	0^{a}	3^{A}	$4(1)^{*c}$	1^{d}	1^{e}	5^{C}	$2(1)^{*a}$	1^{e}	1^{d}	4^{B}	4.0
July	1^{a}	3^{c}	1^{d}	5^{E}	$2(1)^{*e}$	$2(1)^{*b}$	1^{d}	5^{E}	2^{e}	0^{a}	2^{c}	4^{A}	4.6
Aug.	1^{a}	0^{a}	1^{b}	2^{A}	2^{*e}	3^{c}	2^{c}	7^{C}	$2(1)^{*e}$	2^{b}	0^{a}	4^{B}	4.3
Sep.	4^{c}	1^{a}	1^{b}	6^{D}	3^{*d}	3^{c}	1^{b}	7^{C}	$3(1)^{*d}$	$2(1)^{*b}$	1^{b}	6^{D}	6.0
Oct.	1^{d}	3^{c}	3^{c}	7^{C}	1^{d}	0^{d}	2^{b}	3^{D}	2^{c}	0^{d}	1^{a}	3^{D}	4.3

(Figures in parenthesis indicate the population of S. praefectus)

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

4.5.2 Spatial distribution of natural enemies at Irinjalakuda

Population was almost in the same level in all seasons. But it was seen that in December, the natural enemy population was more than that of the pest population. Major enemies noticed, included spiders (55%) and Stethoconus praefectus (45%).

4.5.3 Spatial distribution of natural enemies at Chavakkad

The level of population was same throughout the year. Only slight fluctuations were recorded throughout the year. That was in March-April and also one in November. Among the natural enemies observed, spiders represented about 76 per cent of the population and the rest was S. praefectus (24%).

4.6 Spatial distribution of natural enemies at Ernakulam district

Table 7 shows natural enemies of S. typicus observed from Ernakulam district.

Statistical analysis showed that there is significant difference between population of natural enemies at the different locations in the district. But the mean level of population of natural enemies for the district in toto was same throughout the year. Only slight changes were observed. In July, the pest and natural enemy population was seen in the

Table 7. Spatial distribution of natural enemies of S. typicus at different locations in Ernakulam district at monthly intervals

Month	Vyttila			Total	Mulanthuruthy			Total	Muvattupuzha			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	3^{e}	2^{e}	3^{c}	8^{C}	2^{a}	1^{a}	2^{*d}	5^{A}	3^{e}	2^{e}	2^{d}	7^{B}	6.6
Dec.	1^{d}	1^{d}	3^{c}	5^{E}	1^{d}	1^{d}	2^{b}	4^{A}	2^{c}	2^{c}	1^{a}	5^{E}	4.6
Jan.	2^{b}	2^{c}	$2(1)^{*c}$	6^{C}	2^{b}	1^{d}	1^{d}	4^{D}	2^{b}	1^{d}	1^{d}	4^{D}	4.6
Feb.	$4(1)^{*c}$	1^{a}	1^{*d}	6^{C}	2^{b}	2^{e}	1^{d}	5^{B}	0^{a}	2^{e}	2^{c}	4^{A}	5.0
Mar.	2^{b}	$2(1)^{*c}$	3^{d}	7^{E}	$2(1)^{*b}$	1^{d}	3^{d}	6^{A}	$2(1)^{*b}$	1^{d}	4^{c}	7^{E}	6.6
Apr	$5(3)^{*c}$	$3(1)^{*c}$	4^{e}	9^{C}	2^{b}	2^{*b}	$4(2)^{*e}$	8^{B}	1^{a}	1^{a}	1^{a}	3^{A}	6.6
May	$2(1)^{*d}$	2^{b}	3^{c}	7^{C}	$2(1)^{*d}$	2^{b}	1^{d}	5^{A}	$3(1)^{*c}$	2^{b}	1^{d}	6^{D}	6.0
Jun	2^{d}	1^{b}	0^{d}	3^{D}	3^{c}	1^{b}	1^{c}	5^{C}	2^{d}	1^{b}	0^{d}	3^{D}	3.6
July	$3(1)^{*c}$	1^{b}	1^{d}	5^{E}	1^{a}	1^{b}	1^{d}	3^{A}	2^{b}	1^{b}	2^{c}	5^{E}	4.3
Aug.	2^{*e}	0^{d}	0^{a}	2^{D}	1^{a}	0^{d}	1^{b}	2^{D}	$2(1)^{e}$	1^{c}	2^{c}	5^{C}	3.0
Sep.	$3(1)^{*e}$	1^{a}	1^{b}	5^{D}	2^{a}	2^{e}	1^{b}	5^{D}	3^{e}	2^{e}	1^{b}	6^{C}	5.3
Oct.	3^{b}	3^{e}	1^{d}	7^{E}	3^{b}	1^{a}	2^{c}	6^{A}	3^{b}	3^{e}	1^{d}	7^{E}	6.6

(Figures in parenthesis indicate the population of S. praefectus)

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

same level and in December, the natural enemy population was higher than that of pest population.

4.6.1 Spatial distribution of natural enemies at Vyttila

The population was found to remain in the same level throughout the year. Very slight changes were recorded in March, April, May and also in November. In July it was higher than that of the pest population. Major natural enemies noticed were spiders (81%) and S. praefectus (19%).

4.6.2 Spatial distribution of natural enemies at Mulanthuruthy

The trend was in the same way with slight changes in the level of population in April and August. But in other months the level of population was almost equal. Among the natural enemies recorded, spiders constituted 83 per cent and only 17 per cent of the population is comprised of other natural enemies.

4.6.3 Spatial distribution of natural enemies at Muvattupuzha

The level of population was almost same throughout the year. In June and December the natural enemy population and the pest population were observed in the same level. The major identified predator was spiders.

4.7 Spatial distribution of natural enemies in Kottayam district

The number of natural enemies recorded in Kottayam district is shown in Table 8.

The statistical analysis showed that, there was difference between the distribution of natural enemies in different locations of Kottayam.

For Kottayam district, the level of natural enemy population remained constant throughout the year. The level shows a slight increase in March, April and in December.

4.7.1 Spatial distribution of natural enemies at Kozha

Population level was almost same with a slight variation in March-April and also in October. Among the natural enemies, spiders were identified as the major one (88%) and next to it was S. praefectus (12%).

4.7.2 Spatial distribution of natural enemies at Kumarakom

The trend was almost similar and the level of population was found to remain constant throughout the year. Spiders were recorded highest (78%) and S. praefectus was in second position (22%).

Table 8. Spatial distribution of natural enemies of S. typicus at different locations in Kottayam district at monthly intervals

Month	Kozha			Total	Kumarakam			Total	Thodupuzha			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	1^{d}	3^{e}	2^{b}	6^{B}	1^{d}	3^{e}	$2(1)^{*b}$	6^{B}	2^{c}	2^{a}	2^{b}	6^{B}	6.0
Dec.	2^{c}	1^{d}	2^{e}	5^{E}	1^{b}	3^{c}	1^{a}	5^{E}	0^{a}	1^{d}	2^{e}	3^{A}	4.3
Jan.	2^{c}	0^{a}	2^{d}	4^{B}	1^{b}	4^{c}	3^{c}	8^{C}	0^{a}	1^{b}	2^{d}	3^{A}	5.0
Feb.	1^{a}	2^{b}	2^{e}	5^{D}	$2(1)^{*e}$	3^{c}	1^{a}	6^{C}	2^{e}	1^{a}	2^{e}	5^{D}	5.3
Mar.	3^{c}	2^{d}	4^{e}	9^{C}	2^{b}	2^{d}	4^{e}	8^{B}	1^{a}	3^{c}	1^{a}	5^{A}	7.3
Apr	$3(1)^{*e}$	$2(1)^{*b}$	2^{d}	7^{B}	3^{*e}	$2(1)^{*b}$	$4(2)^{*c}$	9^{E}	1^{a}	2^{b}	2^{d}	5^{A}	7.0
May	$2(1)^{*e}$	2^{b}	1^{b}	5^{B}	1^{*a}	2^{b}	1^{b}	5^{B}	2^{e}	$2(1)^{*b}$	1^{b}	5^{B}	5.0
Jun	$3(1)^{*b}$	1^{e}	1^{d}	5^{B}	4^{c}	1^{e}	1^{d}	6^{C}	1^{a}	0^{a}	3^{c}	4^{A}	5.0
July	2^{d}	1^{b}	0^{d}	3^{D}	$2(1)^{*d}$	1^{b}	0^{d}	3^{D}	3^{c}	1^{b}	1^{c}	5^{C}	3.6
Aug.	1^{a}	1^{b}	0^{d}	2^{A}	$2(1)^{*e}$	1^{b}	3^{c}	6^{C}	2^{e}	1^{b}	0^{d}	3^{B}	3.6
Sep.	3^{e}	0^{a}	0^{a}	3^{D}	$3(2)^{*e}$	$2(1)^{*c}$	1^{e}	6^{C}	1^{a}	1^{b}	1^{e}	3^{D}	4.0
Oct.	$4(2)^{*c}$	$3(1)^{*c}$	0^{d}	7^{E}	$3(1)^{*b}$	$2(1)^{*b}$	2^{c}	7^{E}	2^{a}	0^{a}	0^{d}	2^{A}	5.3

(Figures in parenthesis indicate the population of S. praefectus)

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

4.7.3 Spatial distribution of natural enemies at Thodupuzha

The level of population was almost equal throughout the year. In June-July and December it was equal to that of the pest population. Among the natural enemies, spides were recorded as the major one.

4.8 Spatial distribution of natural enemies in Alappuzha district

Table 9 shows the observations on natural enemies of S. typicus from Alappuzha district.

Statistical analysis showed that there is no significant difference between the populations of different locations in Alappuzha.

The population remained constant throughout the year. In December, it was equal to that of the pest population.

4.8.1 Spatial distribution of natural enemies at Cherthala

Population level was almost equal throughout the year. In July and December the level of population was equal to that of pest population. Among this, spiders are identified as the major one (82%). Another important predatory group was the mixrid bug S. praefectus (18%).

Table 9. Spatial distribution of natural enemies of S. typicus at different locations in Alappuzha district at monthly intervals

Month	Cherthala			Total	Kayamkulam			Total	Mavelikkara			Total	Mean total
	Top	Middle	Bottom		Top	Middle	Bottom		Top	Middle	Bottom		
Nov.	2^{c}	2^{b}	$3(1)^{*e}$	7^{E}	1^{d}	$4(1)^{*c}$	$2(1)^{*a}$	7^{E}	1^{d}	1^{a}	3^{e}	5^{A}	6.3
Dec.	2^{e}	1^{a}	2^{b}	5^{A}	1^{a}	3^{c}	2^{b}	6^{E}	2^{e}	2^{b}	$2(1)^{*b}$	6^{E}	5.6
Jan.	3^{c}	2^{*b}	2^{d}	7^{B}	2^{d}	4^{c}	$2(1)^{*d}$	8^{C}	2^{d}	0^{a}	$4(2)^{*c}$	6^{A}	5.2
Feb.	1^{*e}	3^{e}	3^{c}	7^{C}	0^{a}	3^{e}	2^{d}	5^{D}	1^{e}	2^{a}	$2(1)^{*d}$	5^{D}	5.6
Mar.	2^{e}	2^{b}	2^{b}	6^{E}	2^{e}	0^{a}	2^{b}	4^{A}	1^{a}	3^{c}	2^{b}	6^{E}	5.3
Apr	4^{*b}	2^{e}	1^{d}	7^{B}	$4(2)^{*b}$	2^{e}	2^{c}	8^{C}	$4(2)^{*b}$	1^{a}	1^{d}	6^{A}	7.0
May	$4(3)^{*c}$	2^{c}	2^{c}	8^{C}	$3(2)^{*b}$	1^{d}	1^{d}	5^{B}	2^{a}	1^{d}	1^{d}	4^{A}	5.6
Jun	2^{d}	1^{d}	2^{c}	5^{B}	$2(1)^{*d}$	1^{d}	1^{d}	4^{A}	$3(2)^{*c}$	3^{c}	1^{d}	7^{C}	5.3
July	1^{a}	1^{b}	2^{e}	5^{D}	$3(2)^{*e}$	1^{d}	1^{a}	5^{D}	$3(2)^{*e}$	2^{c}	$2(1)^{*e}$	7^{C}	5.6
Aug.	4^{c}	1^{*b}	2^{e}	7^{C}	1^{a}	1^{*b}	2^{e}	4^{A}	3^{b}	1^{b}	1^{a}	5^{B}	5.3
Sep.	$4(2)^{*c}$	2^{e}	2^{e}	8^{C}	$2(1)^{*a}$	1^{*a}	2^{e}	5^{A}	$3(1)^{*b}$	2^{e}	1^{a}	6^{B}	6.3
Oct.	1^{e}	2^{c}	1^{d}	4^{C}	0^{a}	1^{d}	2^{c}	3^{D}	1^{e}	1^{d}	1^{d}	3^{D}	2.6

(Figures in parenthesis indicate the population of S. praefectus)

In each row (month), figures followed by the same letters indicate a non-significant difference in population. Statistical significance in respect of total populations are compared using capital letters.

4.8.2 Spatial distribution of natural enemies at Kayamkulam

Only slight variation in the level of population was noticed through out the year. The identified predators in field included spiders (79%) and S. praefectus (21%).

4.8.3 Spatial distribution of natural enemies at Mavelikkara

The level of population was found to remain constant throughout the year. In July, the population was equal to that of the population level of the pest. But in December it was above the pest level. Eighty one per cent of the field population of the enemies were identified as spiders. The next important predator identified was S. praefectus (21%).

4.9 Host preference of S. typicus

Preference shown by S. typicus on different host plants were studied under glasshouse condition and the mean values were presented on Table 10 (Plate 1).

It was seen that the maximum population of the pest is recorded on coconut leaves. In turmeric and arrowroot, the population recorded was almost equal and the rate of multiplication of the pest on these hosts was low compared to coconut seedlings.

Table 10. Population of S. typicus on different host plants under artificial rearing (number/plants)

No. of S. typicus at definite days after release	Coconut		Turmeric		Arrowroot	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
10 days	0	19	0	19	0	19
20 days	60	4	38	0	30	0
30 days	110	41	55	21	42	12
40 days	78	32	20	20	21	22
50 days	80	32	55	23	45	20
60 days	131	60	54	22	37	28

Plate 1. *Stephanitis typicus* Distant (Heteroptera: Tingidae) lacewing bug of coconut

4.10 Determination of predatory potential of natural enemies

4.10.1 Determination of predatory potential of nymphs of Stethoconus praefectus

The mean values of observations are furnished in the Table 11.

The results showed that the 1st instar S. praefectus consumes an average of 4.7 S. typicus nymphs per day. The consumption rate increased in the second nymphal instar of the predator and the mean consumption recorded was 5.4 nymphs of the host. The rate of consumption showed an increasing trend in third and fourth nymphal stages. In the fifth instar stage, decrease in consumption was recorded and the rate of consumption observed was an average of 5.4 nymphs per day. It was also observed that a nymph of S. praefectus consumed an average of 63 nymphs of S. typicus during its total nymphal life. Nymphs of S. praefectus preferred nymphs of its host, rather than adult S. typicus, which were almost always refused as food.

4.10.2 Predatory potential of adult mirid predator S. praefectus

Table 12 shows the number of S. typicus consumed by the adults of S. praefectus (Plate 2).

Table 11. Number of S. typicus mymphs consumed by the nymphs of S. praefectus

Replication	Ist instar		IInd instar		IIIrd instar		IVth instar		Vth instar			Total
	Ist day	IInd day	Ist day	IInd day	Ist day	IInd day	Ist day	IInd day	Ist day	IInd day	IIIrd day	
1	4	5	5	5	6	8	7	6	7	5	4	62
2	5	5	6	5	7	6	7	6	7	5	5	64
3	4	5	5	6	7	6	8	6	7	6	4	64
4	4	5	6	5	6	7	7	7	7	4	4	62
5	5	5	6	5	6	7	7	6	6	6	4	63
Mean	4.7		5.4		6.6		6.7		5.4			63

Plate 2. Stethoconus praefectus Distant (Heteroptera: Miridae)

Table 12. Number of adult S typicus consumed by the adult of S. praefectus

Replication	Days					Total
	1	2	3	4	5	
1	4	5	5	4	4	22
2	4	6	6	2	-	18
3	5	6	5	5	3	24
4	4	5	6	5	3	23
5	5	6	5	3	-	19

The results showed that the mean consumption was 4.6 adults per day. The adults lived for a maximum of 5 days and devoured an average of 4.6 adults of S. typicus during its adult stage. On an average, a total of 23 adults of S. typicus were consumed by S. praefectus adult in its adult life.

4.10.3 Predatory potential of adult mirid predator

Table 13 shows the number of S. typicus nymphs consumed by the adults of S. praefectus.

The adults lived for a maximum of 5 days and devoured an average of 5 nymphs of S. typicus per day during its adult stage. A total of about 25 nymphs were consumed by the adult mirid during its adult life.

4.10.4 Predatory potential of spider Phidippus sp. (No.1)

The observations are presented in Table 14. The results showed that the spider Phidippus sp. predates the adult lace wing bugs and rarely consumed the nymphs. The mean consumption recorded was 3.7 adults of S. typicus per day (Plate 3).

4.10.5 Predatory potential of spider Phidippus sp. (No.2)

It was observed that another Phidippus sp. also predates the lace wing bug. The observations recorded are presented in the Table 15 (Plate 4).

Table 13. Number of S typicus nymphs consumed by the adult of S. praefectus

Replication	Days					Total
	1	2	3	4	5	
1	4	5	6	5	-	20
2	5	6	6	4	4	25
3	4	4	5	6	4	23
4	5	6	5	5	-	21
5	4	6	6	5	-	21

Table 14. Consumption of S. typicus by the spider Phidippus spp. (Species No.1)

Replication	Days					Mean
	1	2	3	4	5	
1	3	4	4	4	4	3.8
2	4	4	4	4	4	4.0
3	3	3	4	4	3	3.4
4	4	4	4	4	4	4.0
5	4	3	3	4	4	3.6

Table 15. Consumption of S. typica by the spider Phidippus spp. (Species No.2)

Replication	Days					Mean
	1	2	3	4	5	
1	4	3	3	4	4	3.6
2	3	3	4	4	4	3.6
3	2	4	4	3	4	3.4
4	4	4	3	4	4	3.8
5	4	2	4	4	3	3.4

Plate 3. Spider - Phidippus spp. (Species No.1)

Plate 4. Spider - Phidippus spp. (Species No.2)

The mean consumption recorded was 3.5 adult lace wing bug per day.

4.10.6 Predatory potential of the salticid spider (No.1)

Table 16 shows the rate of consumption of lacewing bug by the spider belonging to the family Salticidae (Plate 5).

It was seen that the spider predates an average of 2.8 adult lace wing bugs per day.

4.10.7 Predatory potential of the salticid spider (No.2)

Rate of consumption of adult lace wing bug by another predatory salticid spider is shown in Table 17 (Plate 6).

It was observed that the spider consumed an average of two adults of S. typicus per day.

4.10.8 Predatory potential of the salticid spider (No.3)

Table 18 shows the mean value of adult lace wing bugs consumed by another unidentified predatory spider (Salticidae) (Plate 7).

The results indicate that the spider takes an average of 1.5 adult of S. typicus per day.

Table 16. Consumption of S. typicus by the Salticidae spider No.1

Replication	Days					Mean
	1	2	3	4	5	
1	3	2	2	3	3	2.6
2	3	3	3	2	3	2.8
3	3	3	4	3	3	3.2
4	3	3	3	3	3	3.0
5	3	2	3	3	3	2.8

Table 17. Consumption of S. typicus by the Salticidae spider No.2

Replication	Days					Mean
	1	2	3	4	5	
1	2	2	2	2	2	2.0
2	1	2	2	1	2	1.6
3	2	2	2	2	2	2.0
4	1	1	2	2	2	1.6
5	2	2	2	2	2	2.0

Table 18. Consumption of S. typicus by Salticid spider No.3

Replication	Days					Mean
	1	2	3	4	5	
1	1	2	1	1	1	1.2
2	1	1	1	1	1	1.0
3	1	2	1	1	1	1.2
4	2	1	1	1	2	1.4
5	1	1	2	1	1	1.2

Plate 5. Salticid spider No.1

Plate 6. Salticid spider No.2

Plate 7. Salticid spider No.3

4.10.9 Predatory potential of the Lygaeid bug Geocoris sp.

The mean values of the observations are presented in the Table 19. It was recorded that the bug consumed an average of 7.8 nymphs of the lace wing bug per day (Plate 8).

4.11 Correlation of population of S. typicus and its natural enemies with weather factors

Regression analysis was done using the data for different districts in separation. Correlation matrix for Alappuzha district is furnished as Table 20.

Correlation matrices for Kottayam, Ernakulam and Trichur are furnished as Tables 21, 22 and 23.

It is seen that the population of S. typicus and its natural enemy were not correlated in all the four districts. However, at Trichur the population of the natural enemies were negatively influenced by rainfall.

Table 19. Consumption of S. typicus by the pentatomid predator

Replication	Days					Mean
	1	2	3	4	5	
1	8	7	8	8	8	7.8
2	7	8	8	8	8	7.8

Plate 8. Predatory *Geocoris sp.* Lygaeidae, predator of *S. typicus*

Table 20. Correlation matrix for population of S. typicus, its natural enemies and weather factors in Alappuzha district

	Population of natural enemies	Rainfall (cm)	Relative humidity (%)	Temperature °C (maximum)	Temperature °C (minimum)	Population of S. typicus
Population of natural enemies	1.000					
Rainfall (cm)	-0.369	1.000				
Relative humidity (%)	-0.461	0.812	1.000			
Temperature °C (maximum)	0.468	-0.726	-0.857	1.000		
Temperature °C (minimum)	-0.017	0.115	0.048	0.342	1.000	
Population of S. typicus	0.086	-0.391	-0.498	0.486	0.503	1.000

Table 21. Correlation matrix for population of S. typicus, its natural enemies and weather factors in Kottayam district

	Population of natural enemies	Rainfall (cm)	Relative humidity (%)	Temperature °C (maximum)	Temperature °C (minimum)	Population of S. typicus
Population of natural enemies	1.000					
Rainfall (cm)	-0.269	1.000				
Relative humidity (%)	0.356	0.867	1.000			
Temperature °C (maximum)	0.686	-0.725	-0.726	1.000		
Temperature °C (minimum)	0.546	-0.161	-0.150	0.563	1.000	
Population of S. typicus	0.668	-0.425	0.348	0.652	0.725	1.000

Table 22. Correlation matrix for population of S. typicus, its natural enemies and weather factors in Ernakulam district

	Population of natural enemies	Rainfall (cm)	Relative humidity (%)	Temperature °C (maximum)	Temperature °C (minimum)	Population of S. typicus
Population of natural enemies	1.000					
Rainfall (cm)	-0.542	1.000				
Relative humidity (%)	-0.471	0.809	1.000			
Temperature °C (maximum)	0.607	-0.622	-0.838	1.000		
Temperature °C (minimum)	0.591	0.014	0.051	0.416	1.000	
Population of S. typicus	0.563	-0.393	-0.299	0.594	1.000	

Table 23. Correlation matrix for population of S. typicus, its natural enemies and weather factors in Thrissur district

	Population of natural enemies	Rainfall (cm)	Relative humidity (%)	Temperature °C (maximum)	Temperature °C (minimum)	Population of S. typicus
Population of natural enemies	1.000					
Rainfall (cm)	-0.717	1.000				
Relative humidity (%)	-0.533	0.831	1.000			
Temperature °C (maximum)	0.250	-0.634	0.572	1.000		
Temperature °C (minimum)	-0.115	0.252	0.448	0.078	1.000	
Population of S. typicus	0.069	-0.417	-0.238	0.682	0.439	1.000

Discussion

DISCUSSION

An investigation was carried out to study the distribution of coconut lace wing bug S. typicus (Dist.) and its natural enemy complex in four root (wilt) prone districts of Kerala to assess the biocontrol potential of major natural enemies. The results obtained from the study are discussed below.

5.1 Distribution of S. typicus

Fluctuation in the population of S. typicus was observed throughout the year in all the selected districts and locations for the study. In general the population was at its peak in March, April and May and subsided in July. From August onwards a gradual increase in population was observed and recorded the second peak in October. The number dwindles again to the lowest in December before it was rebuilt from January onwards.

The results from Table 2 and Fig.1 pertaining to Trichur district showed the agreement of the population trends with the general trend. There was not much variation in population between the three identified locations of Trichur viz., Vellanikkara (Fig.1a), Irinjalakuda (Fig.1b) and Chawakkad (Fig.1c).

Fig.1.Population of *S.typicus*,its natural enemies and weather data at Thrissur

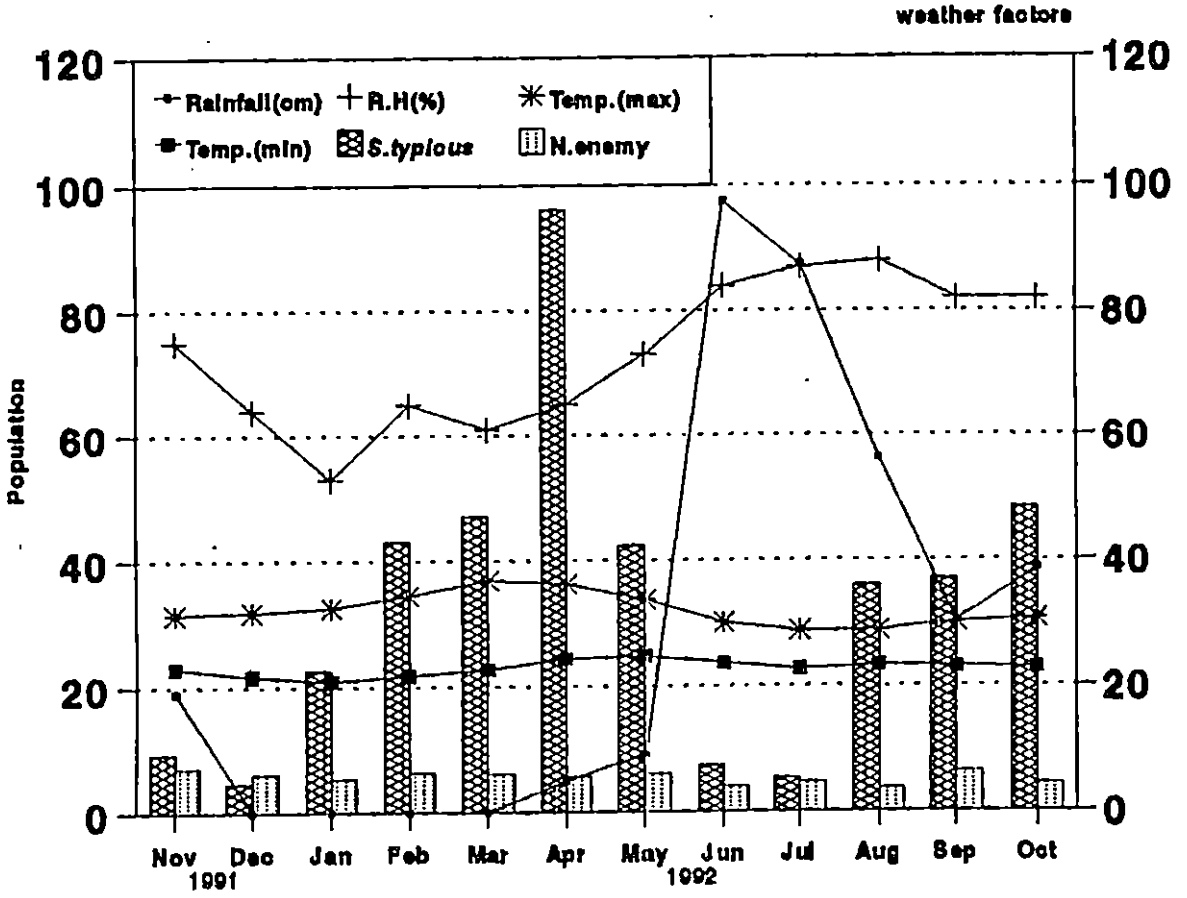


Fig.1a. Population of *S.typicus* and its natural enemies at Vellanikkara (Thrissur District)

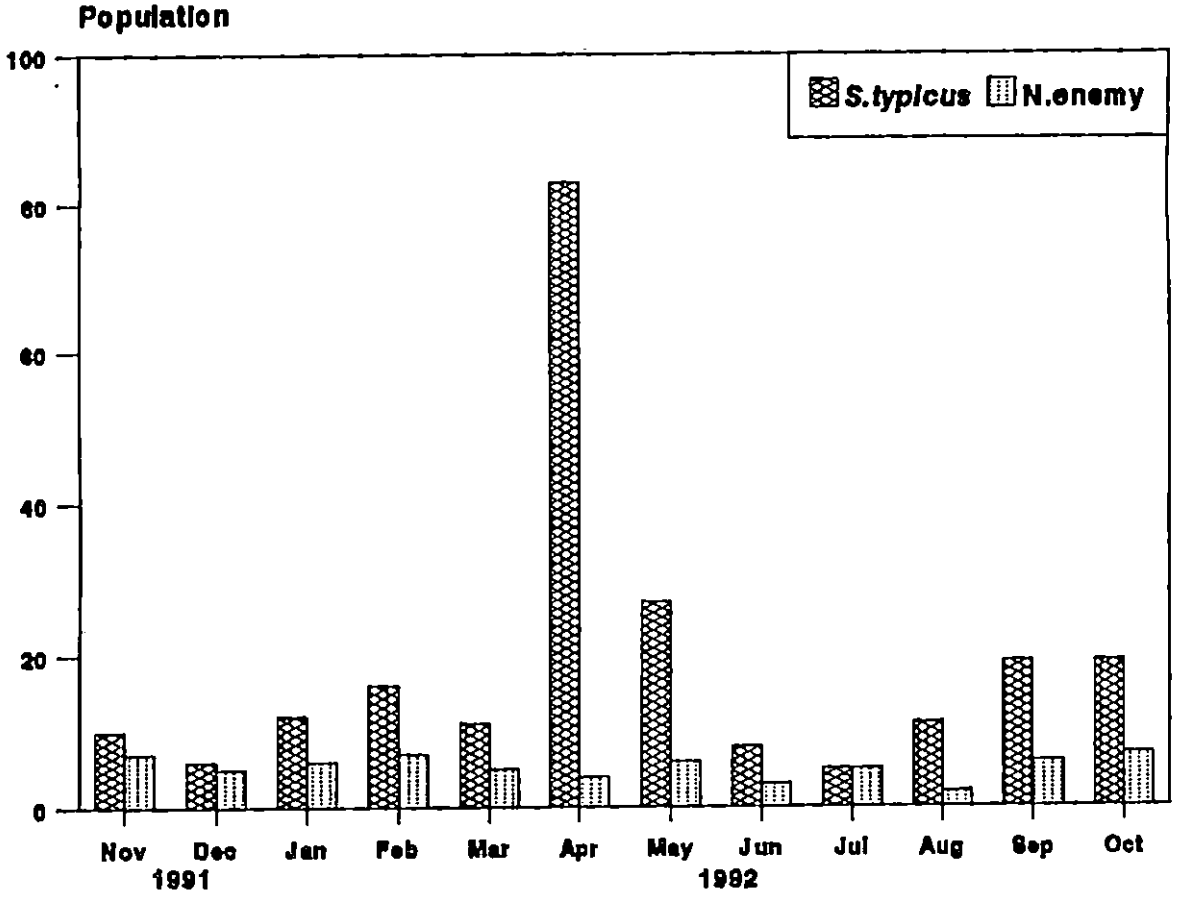


Fig.1b. Population of *S.typicus* and its natural enemies at Irinjalakkuda (Thrissur district)

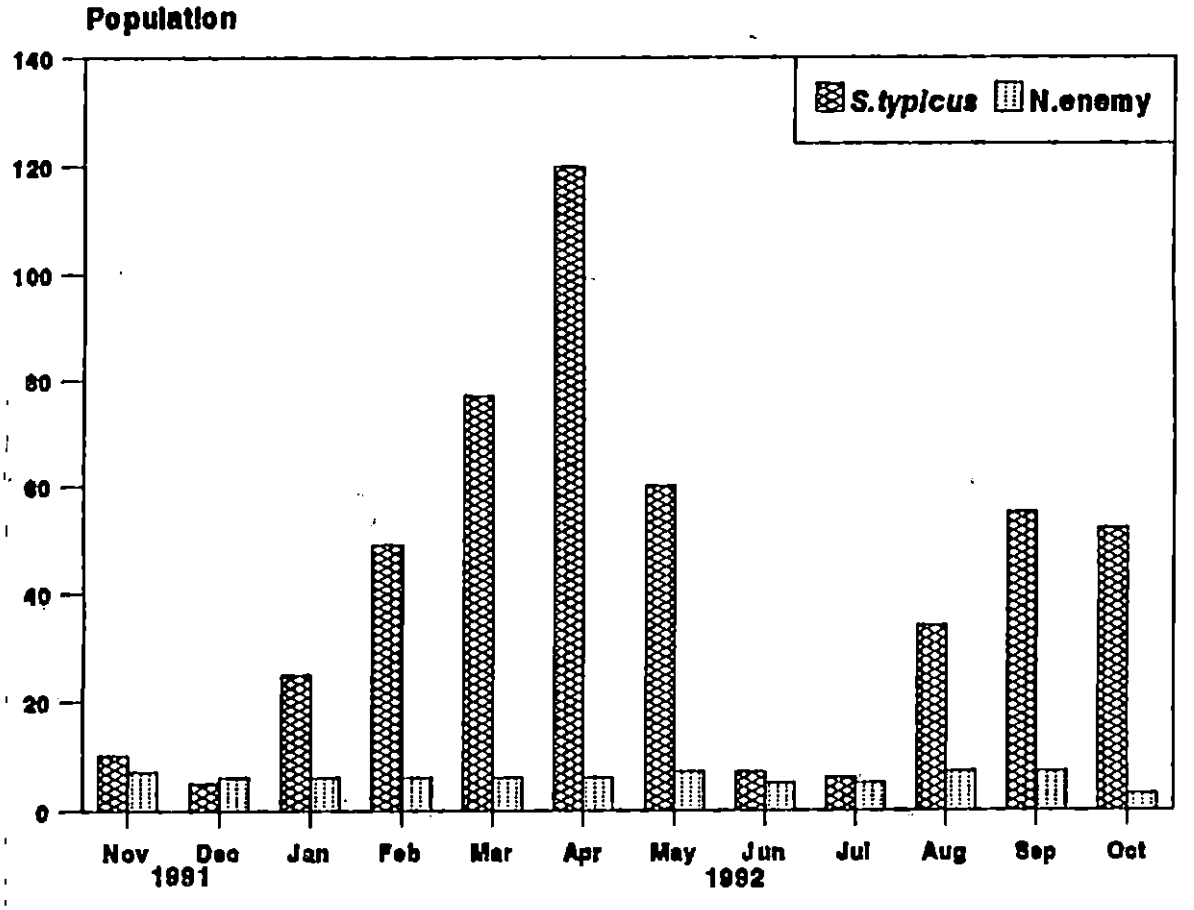
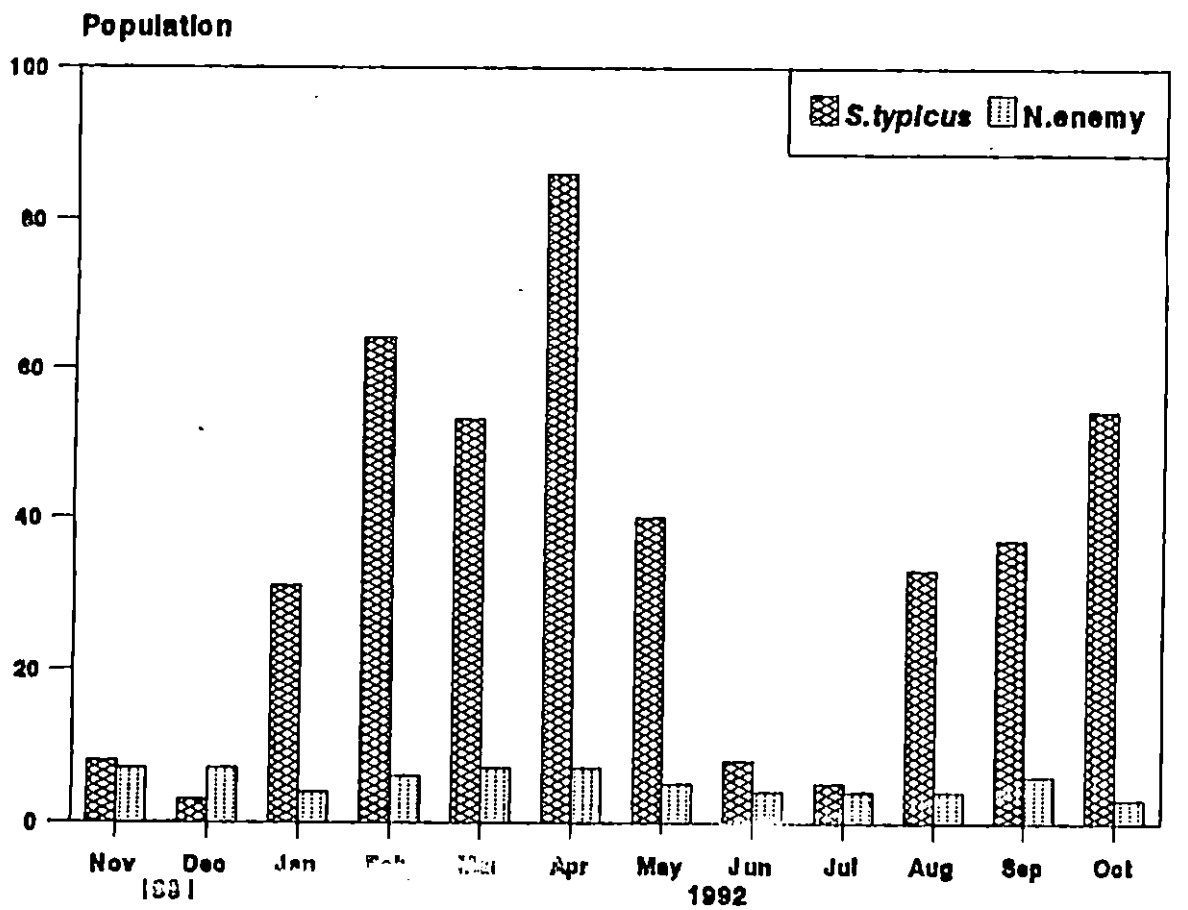


Fig.1c. Population of *S.typicus* and its natural enemies at Chavakkad (Thrissur District)



Approximately identical observations were recorded from Ernakulam district. The results of Table 3 and Fig.2 showed the trend in population. The observations from the identified pockets of Ernakulam districts for the study, i.e., Vyttila (Fig.2a), Mulanthuruthy (Fig.2b) and Muvattupuzha (Fig.2c) were in agreement to the above mentioned general trend of population.

The results from Table 4 and Fig.3 showed that the distribution of pest population in Kottayam district was almost similar to Trichur and Ernakulam. The trend was not different to the general trend of population in Kozha (Fig.3a), Kumarakom (Fig.3b) and Thodupuzha (Fig.3c).

The findings from Table 5 and Fig.4 showed that the population trend in Alappuzha district was in line with the general population trend. The results of observations from Cherthala (Fig.4a), Kayamkulam (Fig.4b) and Mavelikkara (Fig.4c) also agreed with that.

The population of S. typicus in all the districts showed its peak in April. The build up of population started in February or March and declined in May.

Mathen et al. (1967, 1969) had also observed that the maximum population of the tingid occurs in April. They also recorded that more than 75 per cent of the bugs' population

Fig.2. Population of *S.typicus*, its natural enemies and weather data in Ernakulam District

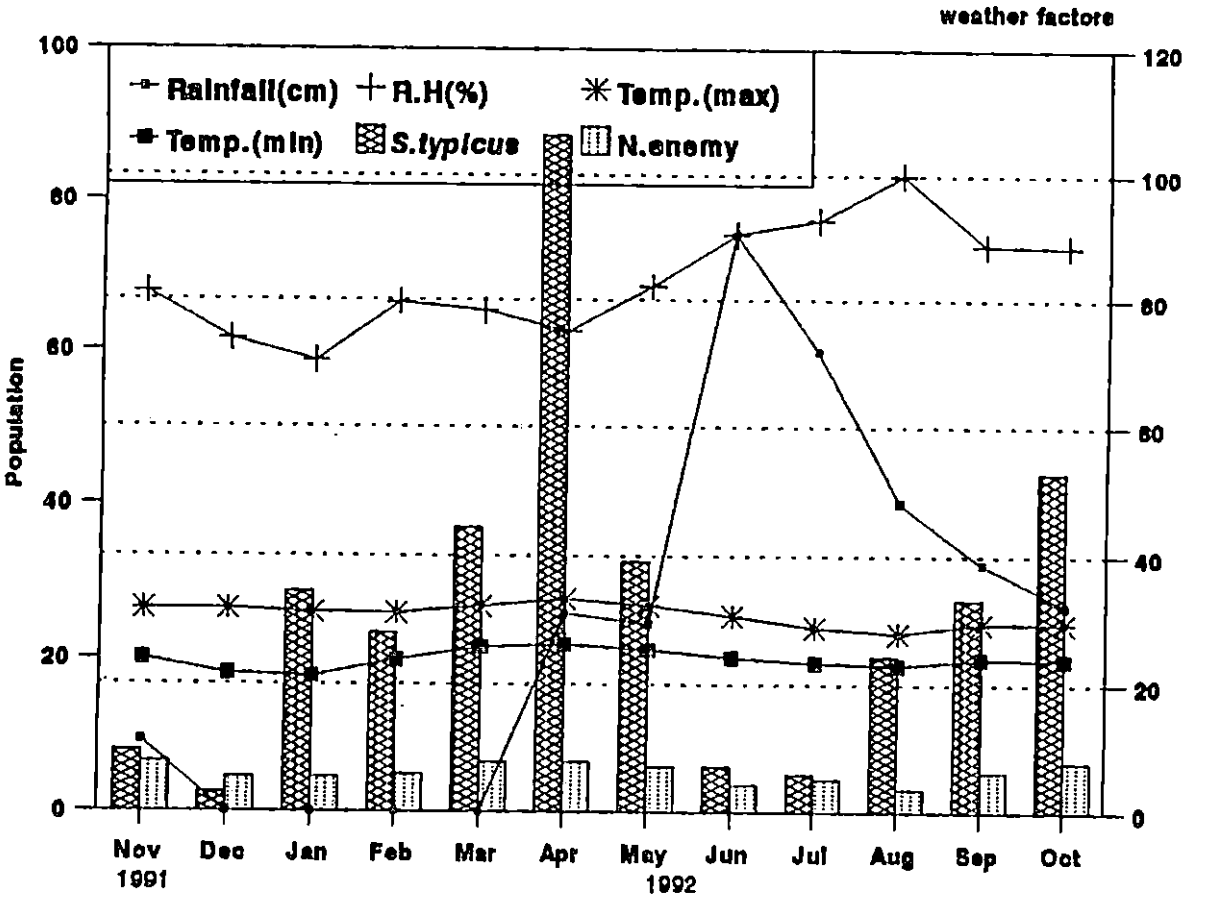


Fig.2a. Population of *S.typicus* and its natural enemies at Vyttila (Ernakulam District)

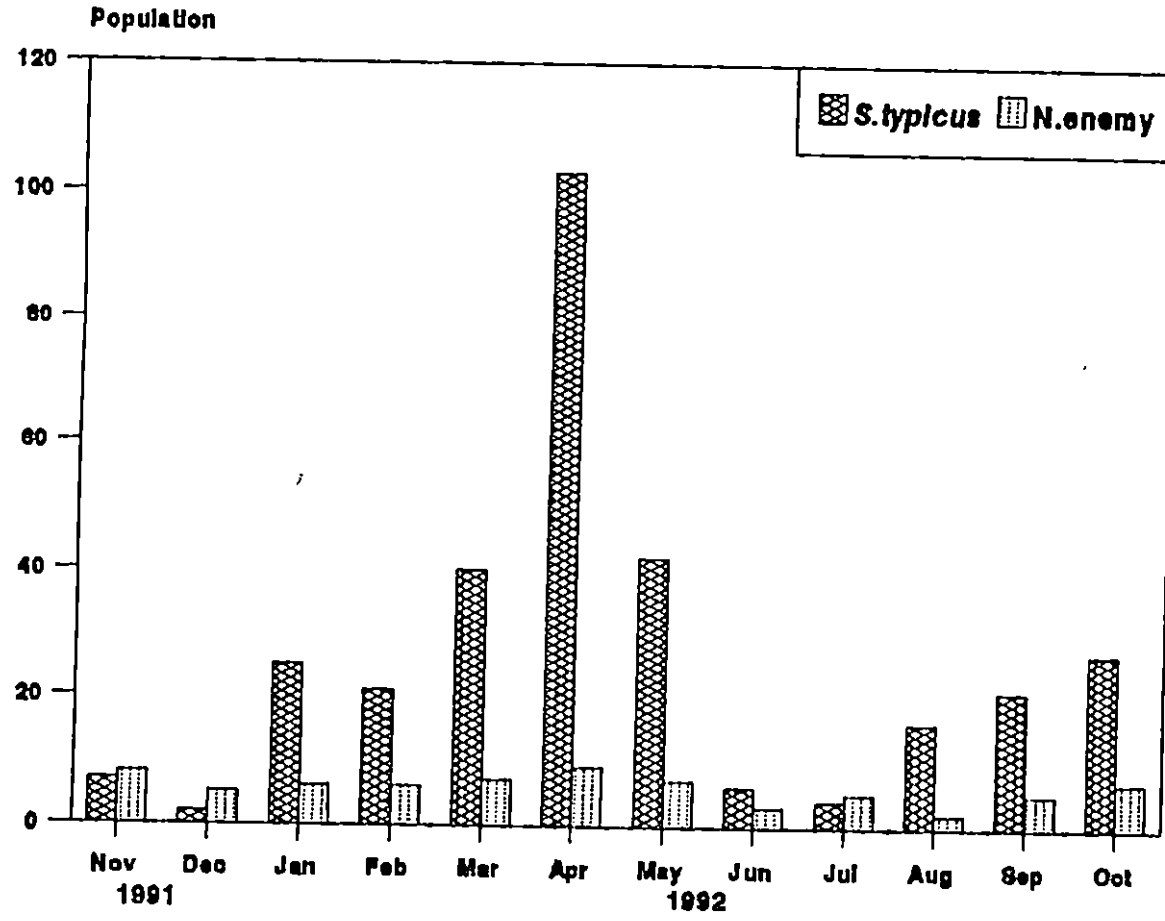


Fig.2b. Population of *S.typicus* and its natural enemies at Mulanthuruthy (Ernakulam District)

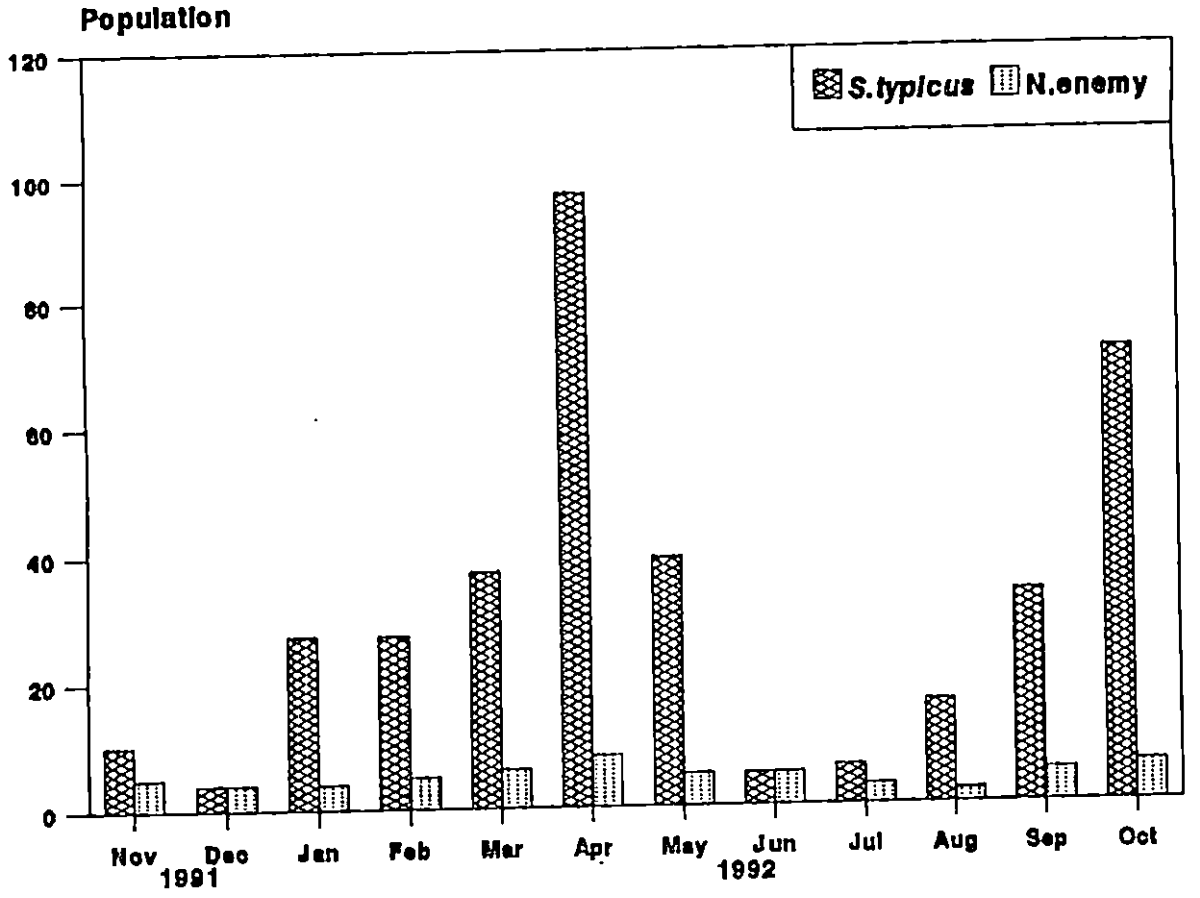


Fig.2c. Population of *S.typicus* and its natural enemies at Muvattupuzha (Ernakulam District)

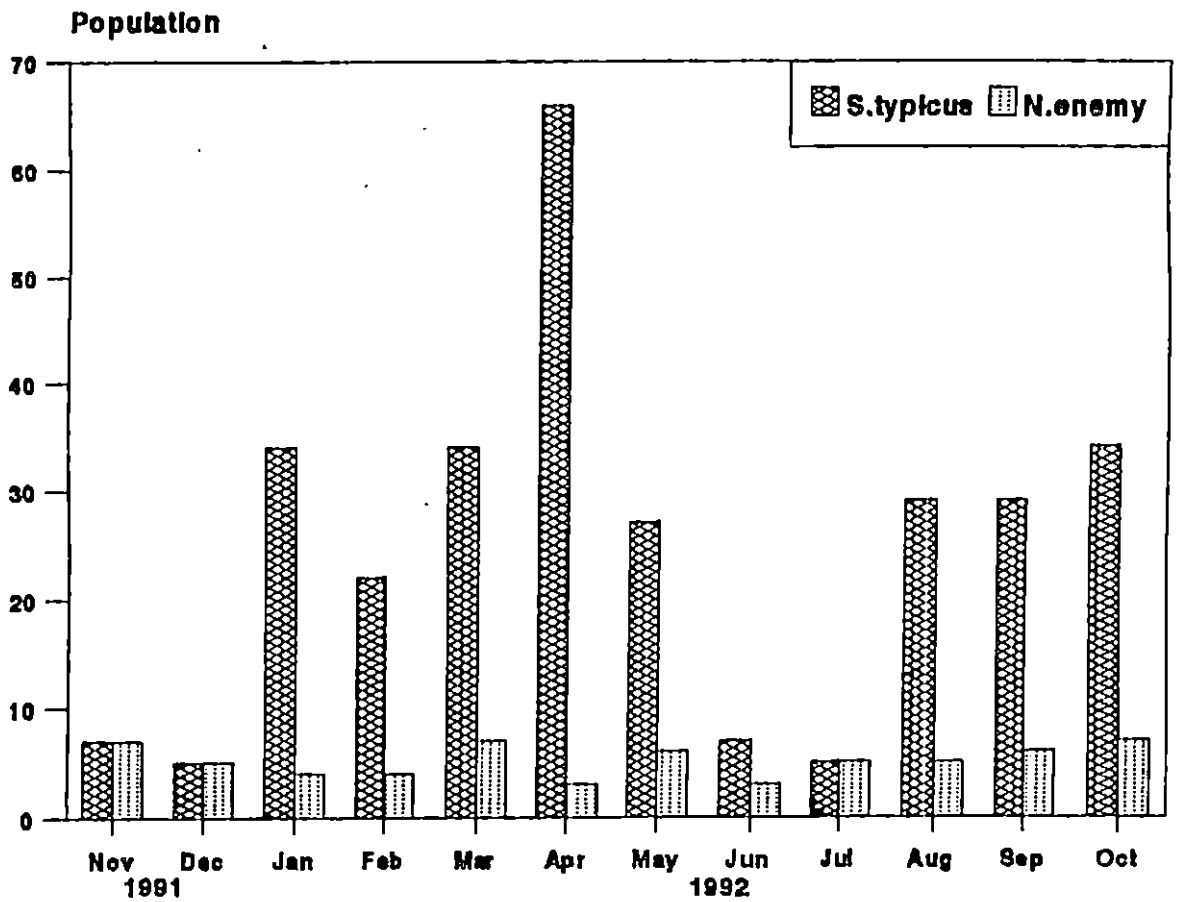


Fig.3.Population of *S.typicus*, its natural enemies and weather data at Kottayam

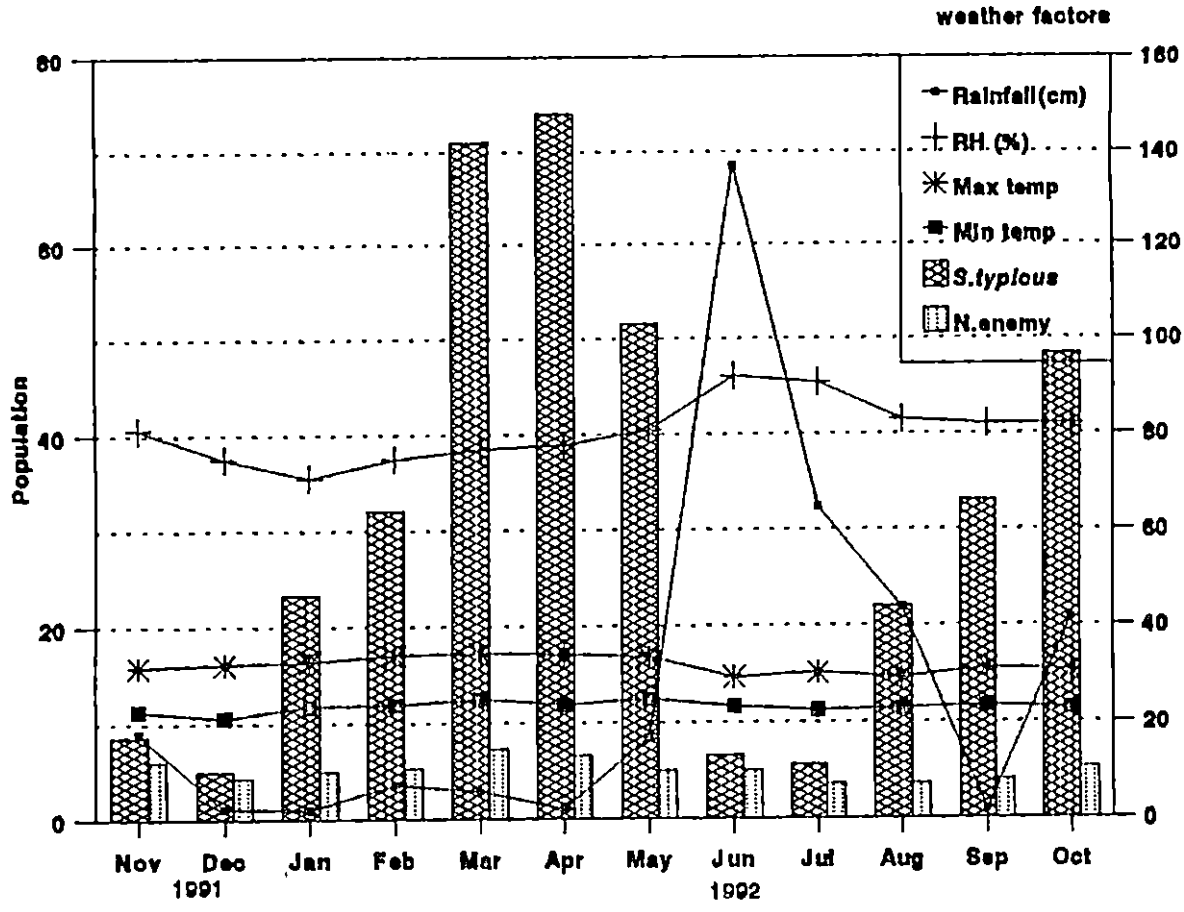


Fig.3a. Population of *S.typicus* and its natural enemies at Kozha (Kottayam District)

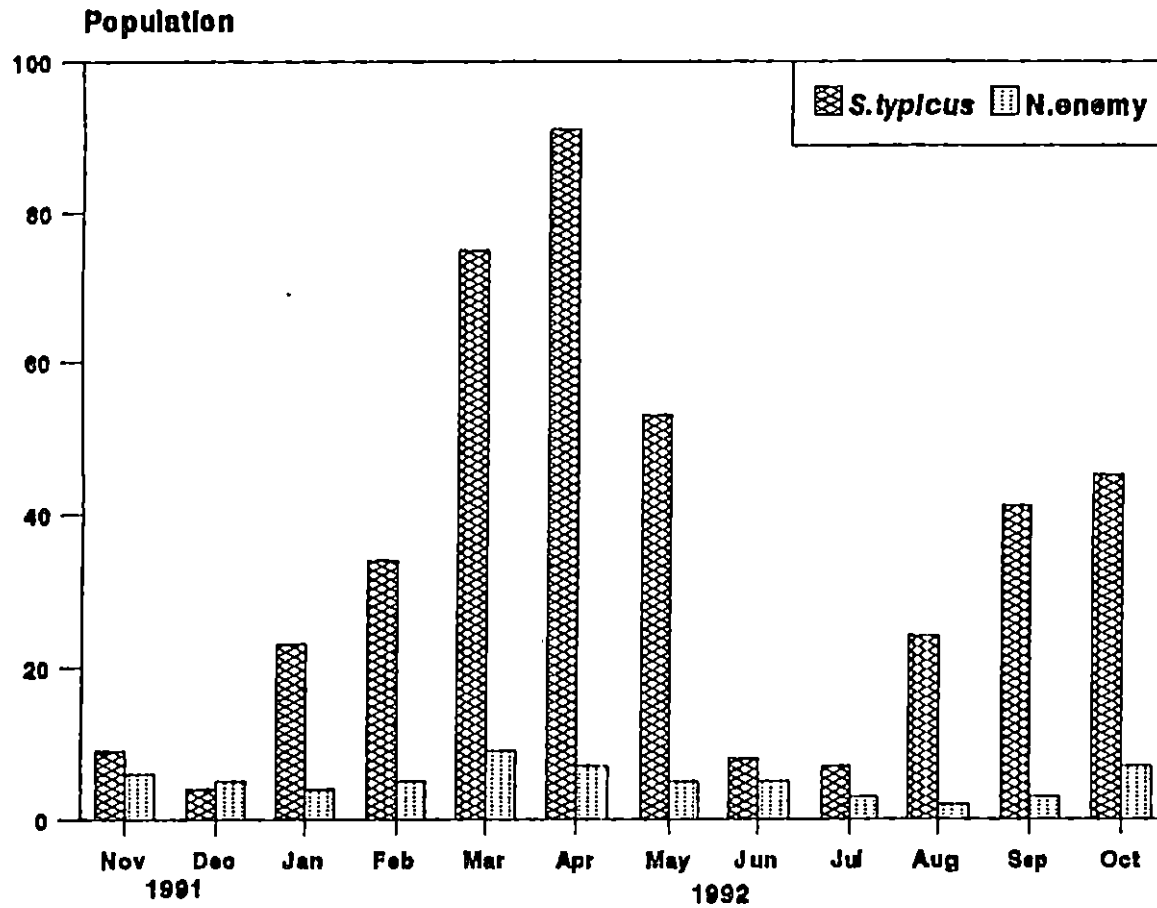


Fig.3b. Population of *S.typicus* and its natural enemies at Kumarakom (Kottayam District)

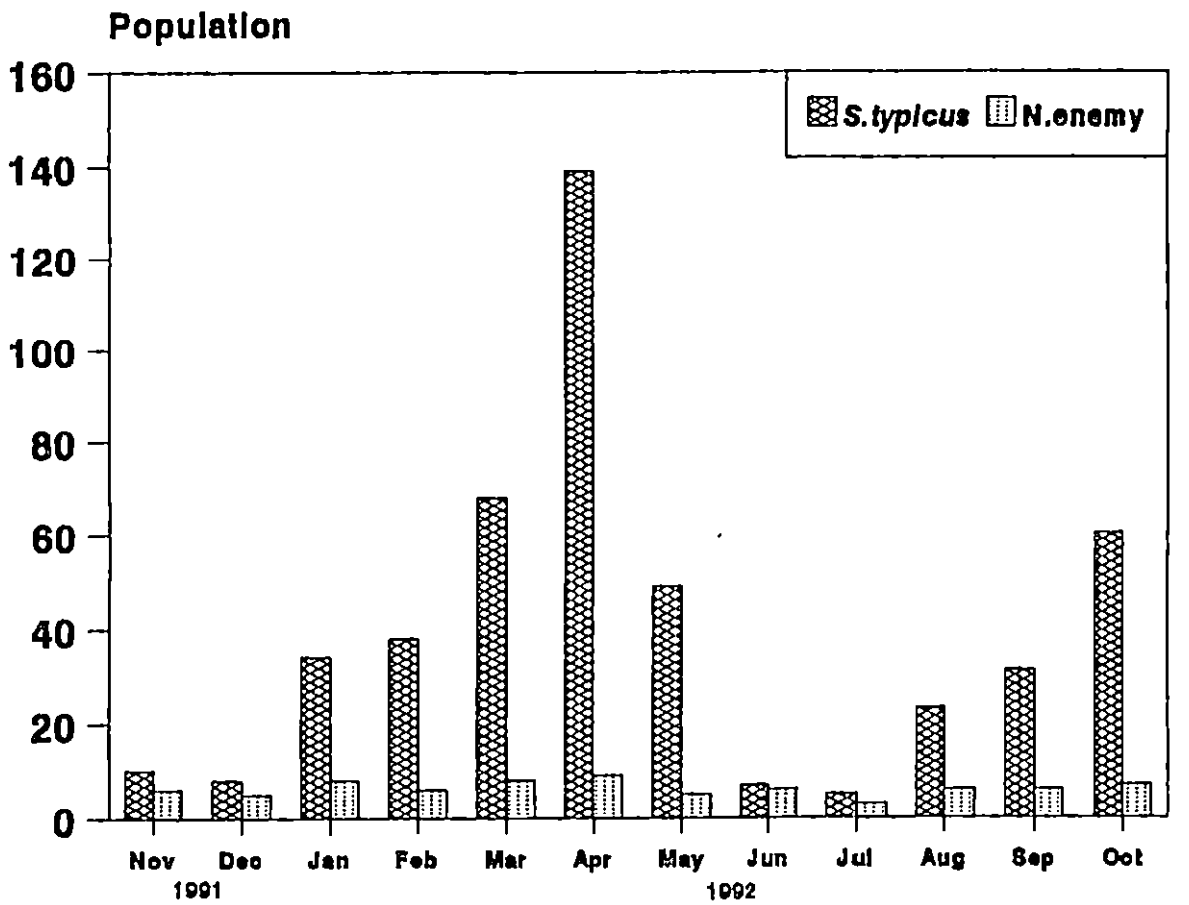


Fig.3c. Population of *S.typicus* and its natural enemies at Thodupuzha (Kottayam district)

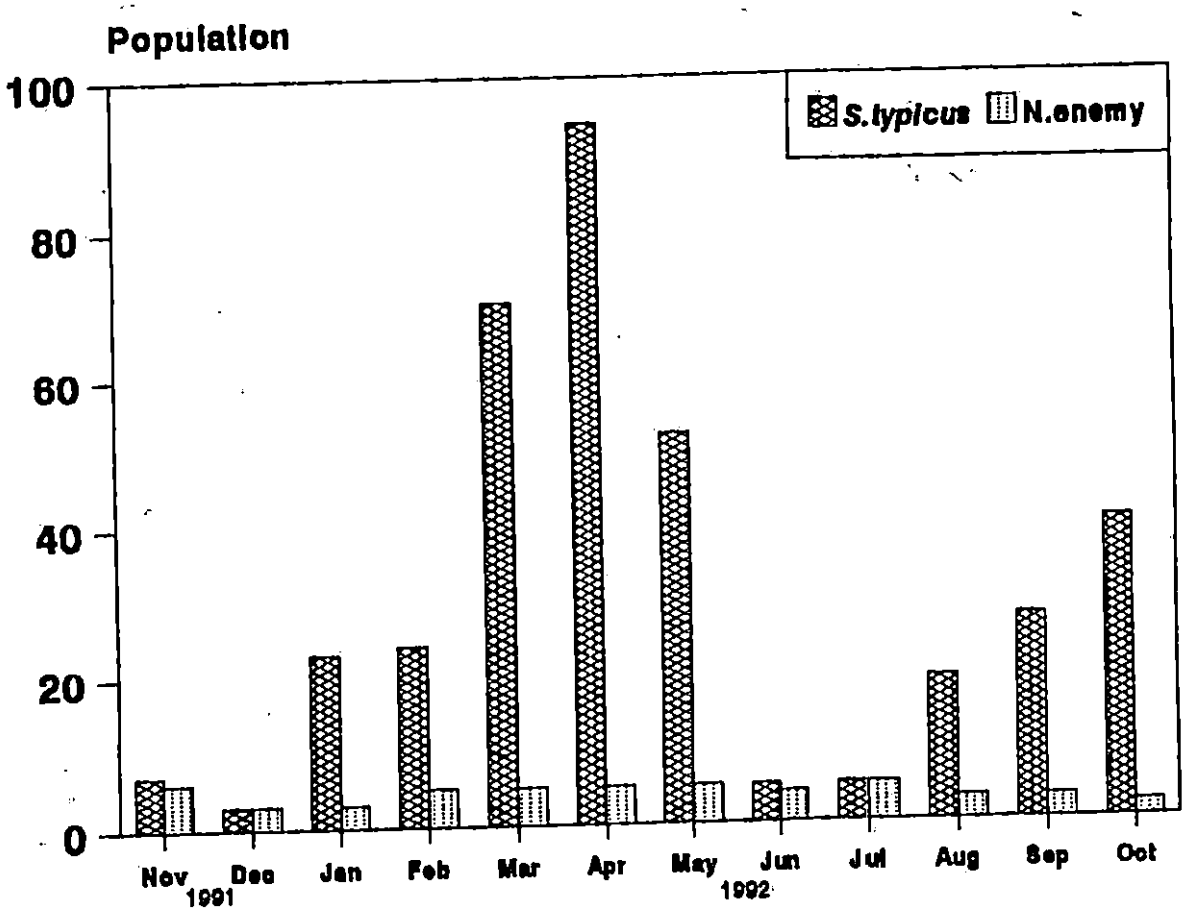


Fig.4. Population of *S.typicus*, its natural enemies and weather data in Alappuzha district

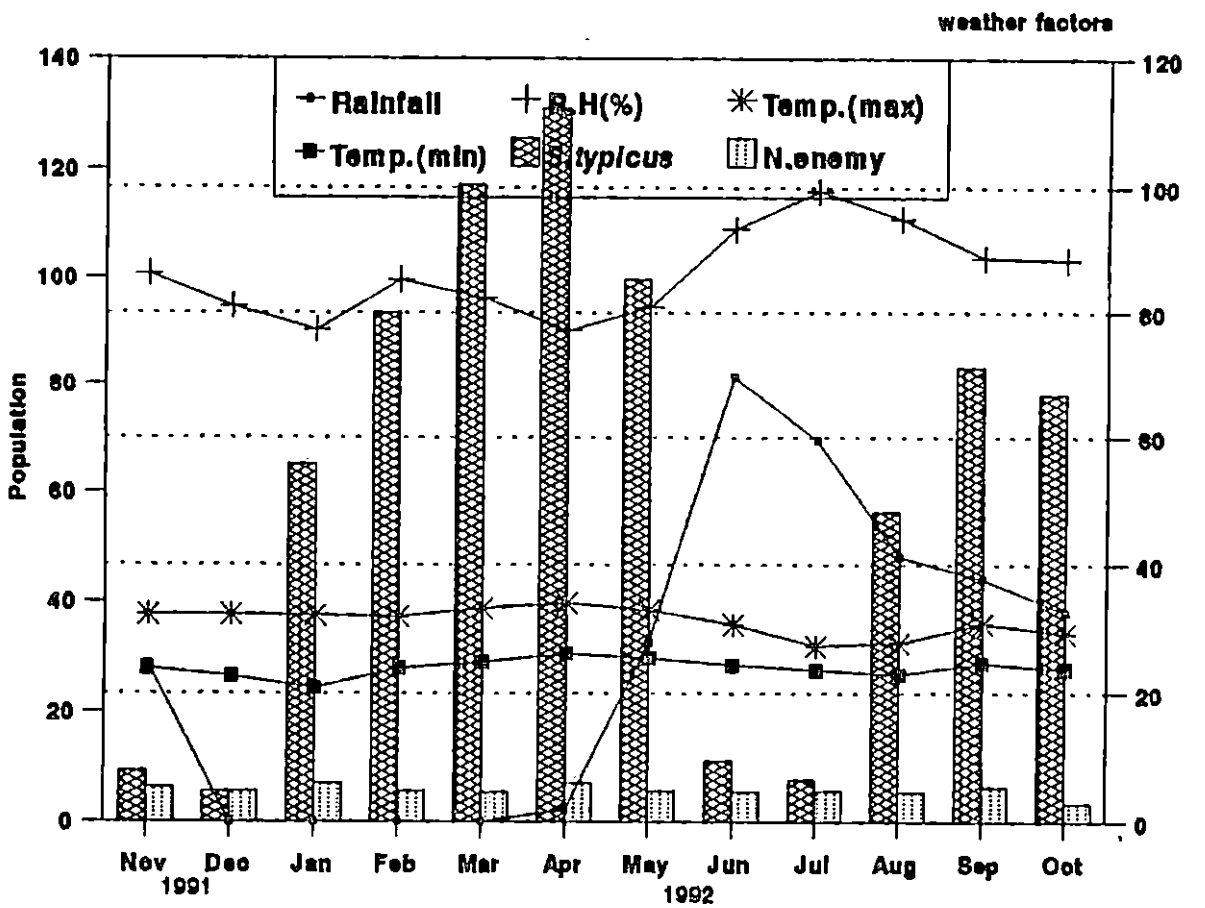


Fig.4a.Population of *S.typicus* and its natural enemies at Cherthala (Alappuzha District)

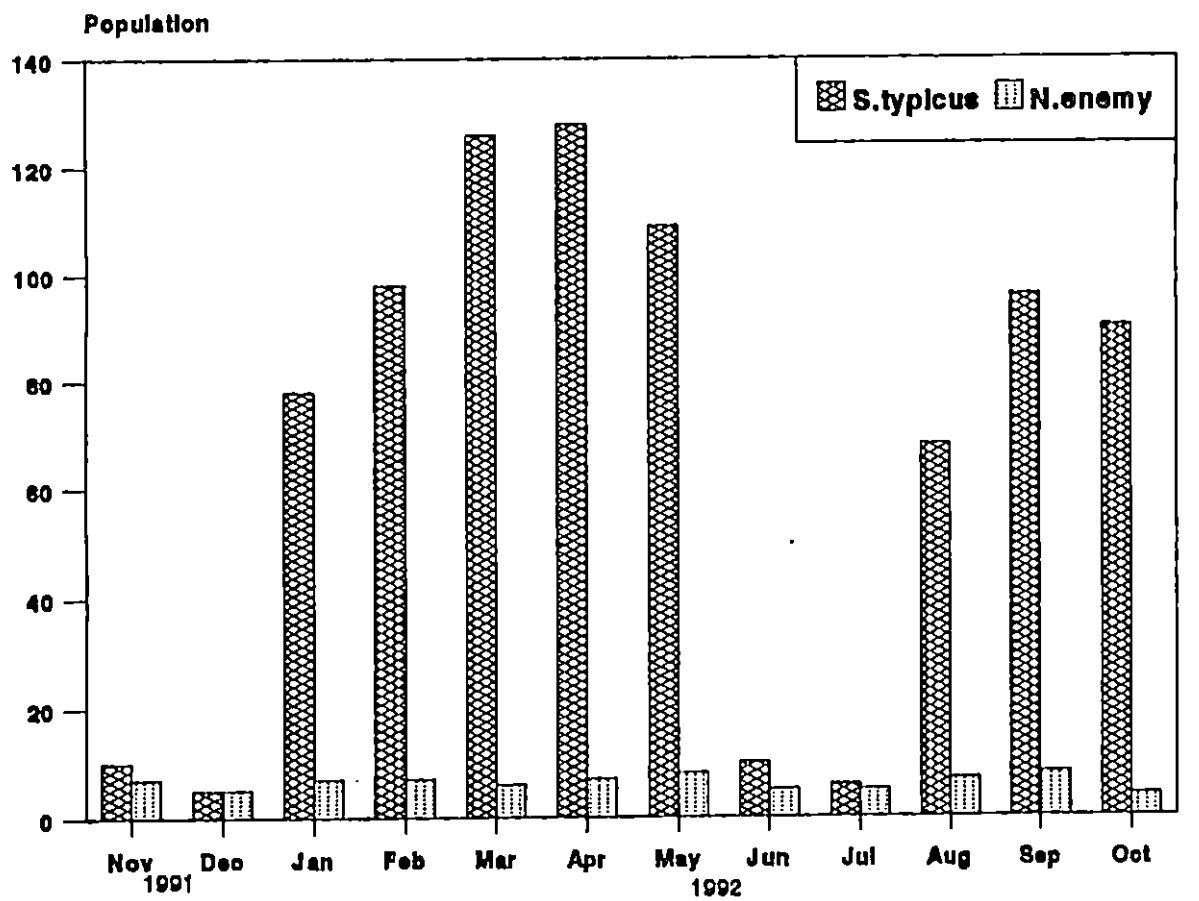


Fig.4b. Population of *S.typicus* and its natural enemies at Kayamkulam (Alappuzha District)

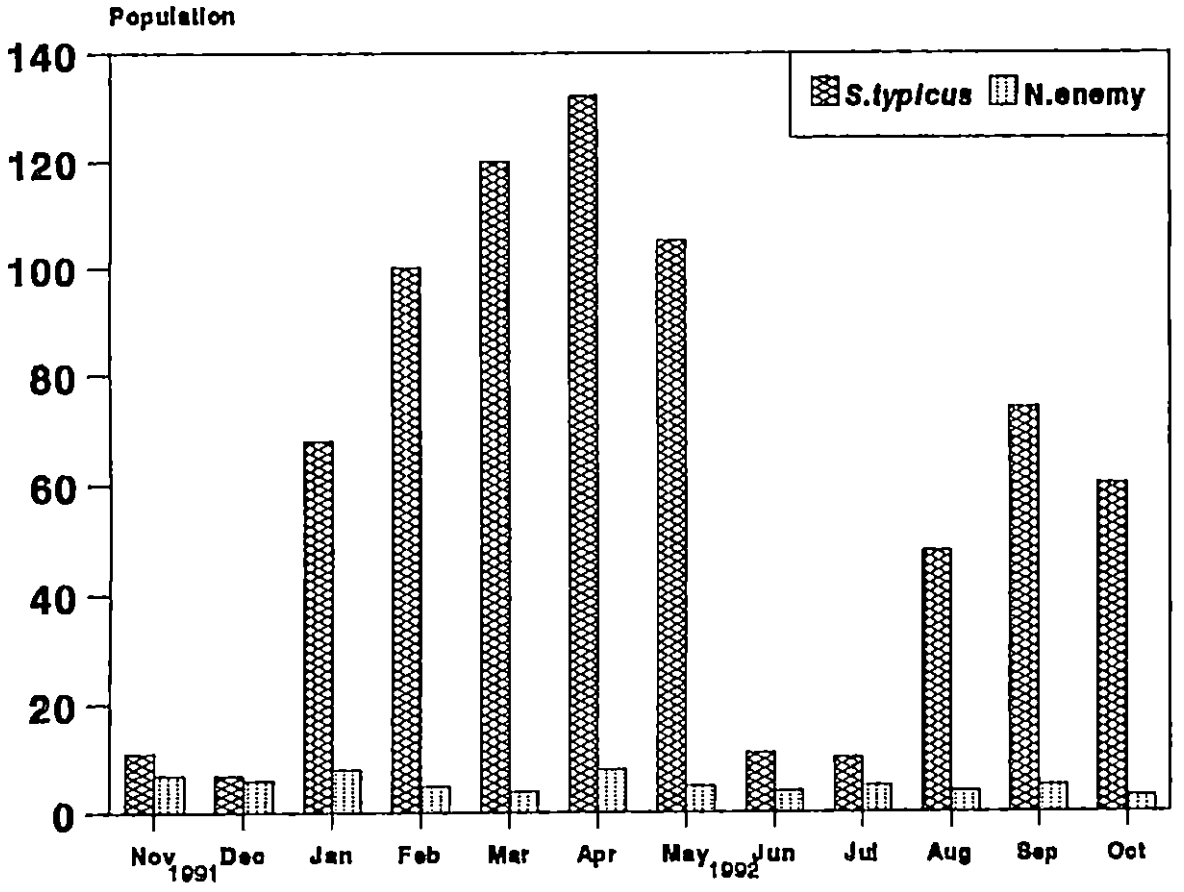
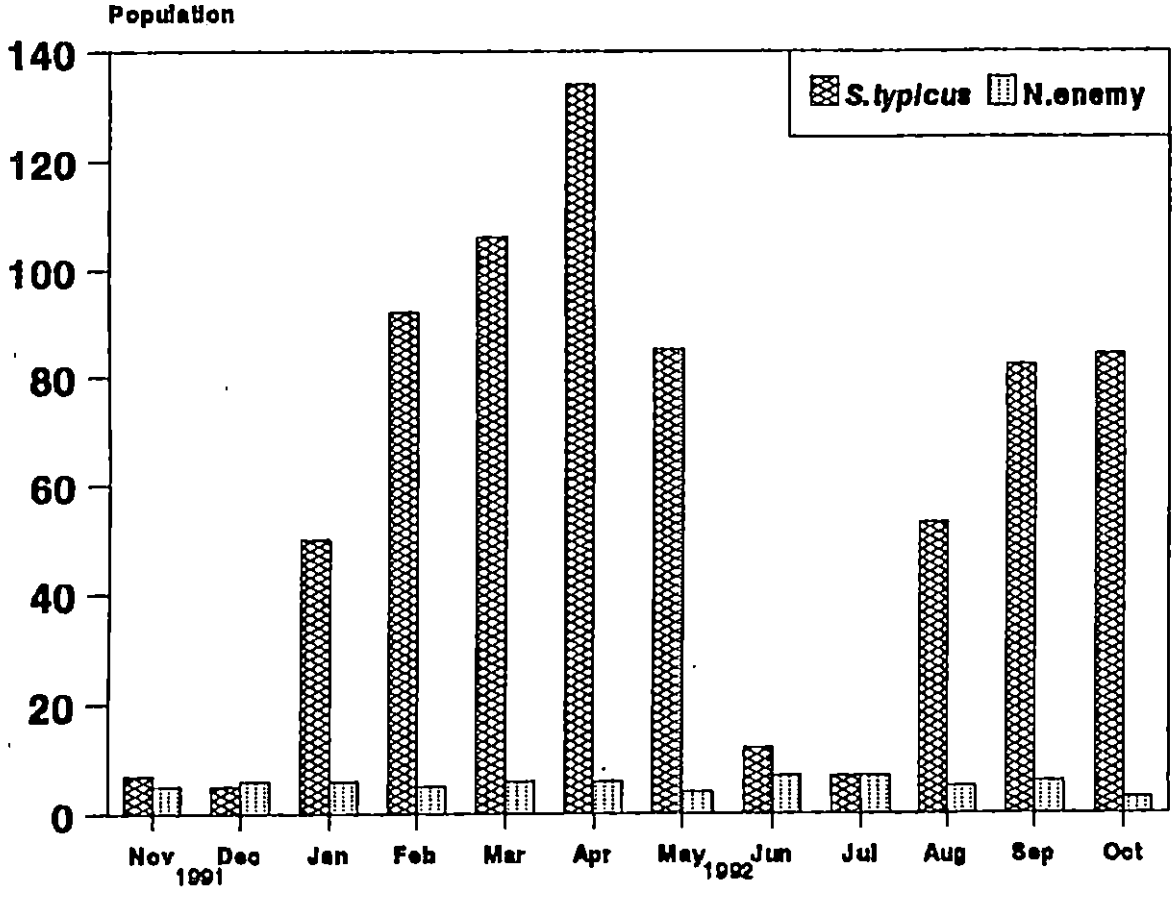


Fig.4c. Population of *S.typicus* and its natural enemies at Mavelikkara (Alappuzha District)



was during March to May. We also have obtained more or less identical results from all the locations in all the four districts. These authors had also pointed out that the abundance of the pest was directly related to sunshine and temperature and that it was negatively correlated with high humidity and rainfall. A perusal of Fig.1 to 4 clearly showed that this was the case with our results also. It was also seen that heavy rains and high humidity commencing from June caused a drastic decline in the population of the tingid bug. During the months of august, September and October, there was a higher day temperature and low rainfall. Hence there was a second build up of population, but it does not scale the heights of April because the relative humidity was still very high. During November-December, eventhough there were no rains, the population was low due to low night temperature times and high relative humidity.

In totality, it was seen that the population abundance of S. typicus was negatively related to rainfall and humidity, while with temperature the relation observed was positive. The results, however, were not statistically significant.

Again it was observed that during dry season (September-May) the population was large, but during rainy season it was reduced. These results were in consonance with the findings of Cheng (1967).

The results from Table 2 to 5 showed the distribution of the insects on coconut leaves. It was observed that the tingid was present in increasing density from outer to inner leaves. Larger number of insects were recorded from inner whorls when compared to middle and outer whorls. These results are comparable to the report of Mathen et al. (1969), who also recorded greater population of the lace wing bugs on the inner leaves.

More than 50 per cent of the population of the lacewing bug was seen to be congregated on the inner most leaves alone. Hence, it may just be sufficient to survey the inner most whorl of leaves alone to arrive at a representative estimate of the population of S. typicus on coconut. This would reduce manpower requirement for the survey, and can also greatly enhance the accuracy of population estimation, by concentrating on the plant parts which harbour the insects most.

5.2 Distribution of natural enemies of S. typicus

In Trichur district the population was found to remain constant throughout the year. The results were shown in Table 6 and Fig.1. A slight increase in population was recorded in February, March, September and November. In December the field population of natural enemies was observed to be more than that of S. typicus.

There is no change in the trend within the different locations in the district, viz., Vellanikkara (Table 6, Fig.1a), Irinjalakkuda (Table 5, Fig.1b) and Chawakkad (Table 6, Fig.1c). The level of natural enemy population was almost equal to that of the population of S. typicus in June-July. The natural enemy level was higher in Irinjalakkuda and Chawakkad during December.

Similar results were recorded from Ernakulam district. From the results of Table 6 and Fig.2, it was observed that the mean level of population of natural enemies for the district in toto was almost stagnant through out the year. But in July the level of pest and natural enemy population was in the same level and in December, the level of pest population was below that of natural enemies.

The trend was same in three selected locations of Ernakulam districts. That is in Vyttila (Table 7, Fig.2a), Mulanthuruthy (Table 7, Fig.2b) and Muvattupuzha (Table 7, Fig.2c).

The results of Table 8 and Fig.3 showed a similar trend in natural enemy population in Kottayam district. The population was found to remain constant through out the year with a slight increase in March, April and December. The

identified locations of the district like Kozha (Table 8, Fig.3a), Kumarakom (Table 8, Fig.3b) and Thodupuzha (Table 8, Fig.3c) also showed a similar trend. In June-July the level of natural enemy population observed was in the same level of the pest.

Results of Table 9 and Fig.4 showed a similar tendency in natural enemy population in Alappuzha district. The population level was almost equal throughout the year. The results were similar in Cherthala (Table 9, Fig.4a), Kayamkulam (Table 9, Fig.4b) and Mavelikkara (Table 9, Fig.4c).

In general it was seen that the population of natural enemy was low throughout the study period. S. praefectus was found to be present throughout the year except in December and January by Cheng (1967). In our studies also there was a decline in population during December and January, but was not totally absent. Cheng (1967) had noted that S. praefetus overwinters during December-January but in Kerala, since there is no definite winter, an overwintering phase may not be needed, and hence, a few insects were found even during these months.

Mathen and Kurian (1972) reported S. praefectus for the first time in Kerala. Pillai and Sathiamma (1986)

observed S. praefectus, spiders and chrysopids on S. typicus. But the seasonal fluctuations of these natural enemy complex has not yet been worked out in Kerala. The population of the natural enemy complex during the study period was very low, probably because of a low population of the host, S. typicus, itself.

5.3 Maintenance of glasshouse culture of S. typicus on different host plants

For the studies on the natural enemies and their predatory/parasitic potential, it was necessary to have a culture of S. typicus throughout the year. It was for this purpose that they were reared on identified host plants including coconut. A better survival on any of these hosts could lead to the establishment of a successful colony of the pest.

5.3.1 Turmeric as a host

Survival of the pest on turmeric leaves was observed in cages condition in glasshouse. Turmeric as a host of S. typicus was recorded by Butani et al. (1985) and Patil et al. (1988).

5.3.2 Arrow root as a host

It was observed that S. typicus could survive on arrow root plants in glasshouse condition. The findings of the host nature of arrowroot plants for S. typicus was reported by Pillai (1991).

5.3.3 Coconut

The pest was also reared on its most abundant host, coconut, by releasing them on young seedlings in the laboratory.

The results (Table 10) showed a higher rate of multiplication and survival on coconut plants than turmeric and arrow root. It was observed that the pest gave more preference to coconut than turmeric and arrow root. Even under the protected environment in the glass house, the rate of multiplication of the pest was not very promising. Eventhough a nucleus culture could be maintained in coconut seedlings, it was never feasible to build up colonies by artificial rearing. Probably the pest could be multiplied under controlled environmental conditions.

5.4 Natural enemies of S. typicus

5.4.1 Stethoconus praefectus (Dist.)

It was identified as one of the important predators of S. typicus. Adults and nymphs of S. praefectus fed on all stages of the lacewing bug. The predatory nature of S. praefectus were reported by Cheng (1967), Mathen et al. (1970, 1972), Vadivelu et al. (1975), Pillai (1985) and Pillai and Sathiamma (1986) and Pillai et al. (1990).

5.4.2 Spiders

The major predatory group on S. typicus was spiders. The results showed that in field as well as in the laboratory, the spiders consumed the adults of S. typicus. The predatory nature of the spider on S. typicus was reported by Pillai and Sathiamma (1986).

5.5 Predatory potential of natural enemies

5.5.1 Predatory potential of nymphs of S. praefectus (Dist.)

S. praefectus was one of the major predators of S. typicus. The results in Table 11 gives the predatory potential of this mirid. There were five nymphal instars for the predator. The mean consumption of the nymphs of the pest by the 1st, 2nd, 3rd, 4th and 5th instars of the predator

nymphs recorded was 4.7, 5.4, 6.6, 6.7 and 5.4 respectively. Maximum consumption was noticed in the 3rd and 4th instar stages. A nymph of S. praefectus consumed an average of 63 host nymphs during its total nymphal period of 11 days. Almost similar results were reported by Mathen et al. (1970), Mathen and Kurian (1972).

5.5.3 Predatory potential of adults of S. praefectus

The results from Table 12 showed that the adults of S. praefectus survived upto five days under laboratory conditions in glass vial. The mean consumption recorded during this period was 4.6 adults of S. typicus. Maximum consumption was recorded on second and third days. On an average a total of 23 adults of S. typicus were consumed by S. praefectus in its adult stage.

5.5.4 Number of host nymphs consumed by adult S. praefectus

It was observed from the results that adult S. praefectus consumed an average of 5 nymphs of S. typicus in a day (Table 13). Similar observations were also recorded by Mathen et al. (1970) and Mathen and Kurian (1972). The adults lived for five days in glass vials in laboratory. Maximum consumption was recorded in second and third day. A total of about 25 nymphs were consumed by the adult mirid predator during its adult life.

The results on the predatory potential of the mirid indicates that both the adults and nymphs have no inhibition in consuming any stage of the tingid S. typicus. In our experiments, we had worked out the predatory potential in isolation i.e., confining either nymphs or adults of the host to the nymphs or adults of the predator. But in nature, such mechanical isolation does not exist. The results however indicate that S. praefectus can be an effective natural enemy of the lace wing bug. The predatory potential is nevertheless, dependent on various extraneous factors such as availability of other alternate food and environmental resistance including biotic and abiotic factors. May be in the field, the predator may live longer, but its search for the host and lack of congregation of the host population may reduce its predatory potential.

5.5.6 Predatory potential of spiders

The major predatory group of natural enemies other than Insects identified in the case of S. typicus was spiders, which occupies a major part in the natural enemy complex of S. typicus. The results of Table 6, 7, 8 and 9 shows the proportion of spiders among the natural enemy complex of S. typicus. All the predatory spiders identified belong to the salticidae family. The results showed that all the spiders predates only the adults of lace wing bug and rarely

consumed the nymphs. From Table 14 it was observed that Phidippus sp. (No.1) consumed an average of 3.5 adults of S. typicus per day. From the results of Table 15 it was observed that another Phidippus sp. (No.2) had consumed an average of 3.5 adults of S. typicus per day. The other identified salticid predatory spiders consumed an average of 2.8 adults (Table 16), 2 adults (Table 17) and 1.5 adults per day (Table 18) respectively.

As a major group in the natural enemy complex of S. typicus spiders plays an important role. Pillai and Sathiamma (1986) had also opined similarly.

It is observed that in general the spiders consume less number of adults per day than S. praefectus. This may be because of the polyphagous nature of the spider. But the pressure of various species of spiders, their numerical abundance, omnipresent nature and hardiness makes them one of the important components of the natural enemy complex. A more comprehensive survey on the abundance and species diversity of spiders is required to pinpoint the exact role that is being played by them in the suppression of the lace wing bug population. Our results, nevertheless indicate the importance of spiders as a major constituent of the natural enemy complex.

5.5.7 Predatory potential of *Geocoris sp.*

Lygaeidae *Geocoris sp.* was found preying on *S. typicus*. The results showed (Table 19) that the bug consumed an average of 7.8 nymphs of lacewing bug per day. This bug was obtained only from Vellanikkara and the population was also very low. Hence eventhough its consumption of host is more, its usefulness as a natural enemy may be limited.

Summary

SUMMARY

An investigation was carried out on the distribution of coconut lace wing bug Stephanitis typicus (Distant) and its natural enemy complex in four selected districts of Kerala during 1991-92. Major natural enemies were identified and an assessment of bio-control potential of these identified natural enemies were also made. The results obtained are summarised below.

A fluctuation in population of S. typicus was observed throughout the year in the field. Two peaks of populations were recorded in an year. The highest peak in March-April and the second highest in September-October. The population peaks were recorded in dry seasons.

The population build up was observed from January onwards and reached its maximum in March-April. From May onwards the population started decreasing and came down to the lowest in June-July. Again an increase in population was observed from August onwards and reached the second peak in September-October.

The trend of population was same in all the twelve locations selected from four districts.

The innermost whorls showed the congregation of the majority of the lacewing bugs, while there was a decrease in the number of S. typicus from inner to the outer whorls.

Population studies of natural enemies of S. typicus revealed the existence of an almost stagnant level of very low population of natural enemies throughout the year in the field. Only very slight fluctuations in populations were recorded. In December the natural enemy population was found almost equal to or more than the pest population. Generally the level of natural enemy population was lower in the field throughout the study period. Among the natural enemies, the major ones recorded in the field included the mirid predator Stethoconus praefectus and salticid spiders, which constituted a majority in the population of natural enemies.

Rearing of S. typicus on different host plants like coconut, turmeric and arrowroot in glass house showed a higher rate of multiplication and pest survival on coconut plants than turmeric and arrowroot.

Major natural enemies recorded in the field included S. praefectus and spiders. S. praefectus was identified as most important in the field and it feeds on the lacewing bug in adult as well as in nymphal stages. In the case of spiders

it preferred the adults of S. typicus and generally ignored the nymphal stages of the pest.

Mirid predator S. praefectus consumed an average of 4.7, 5.4, 6.6, 6.7 and 5.4 nymphs of the pest during its five nymphal stages. During the course of development of the nymph to the adult, it consumed an average of 63 numbers of nymphal stages of the pest. Adults of the mirid predator consumed an average of 4.6 adult hosts per day and the adults lived for a maximum of five days in the laboratory. A total of 23 adults of the tingid bug was consumed by the predator during its adult stage.

The adults of mirid bug consumed nymphs of S. typicus also and averages 5 nymphs per day. On an average a total of 25 nymphs were consumed by the mirid predator, within the five days of adult life.

Another group of natural enemies observed in the field was spiders. It was recorded that Phidippus sp (No.1) consumed an average of 3.5 adults of S. typicus per day. The rate of consumption of Phidippus sp (No.2) recorded was 3.5 adults. The salticid spiders also consumed the adults of S. typicus. The rate of consumption recorded was 2.8, 2 and 1.5 adult per day by the salticid spiders 1, 2 and 3 respectively.

Study of the predatory potential of the Lygaeid Geocoris sp. showed that the bug consumed on an average, 7.8 nymphal stages of the pest per day.

References

REFERENCES

Butani, D.K. 1985. Spices and pest problems. *Pesticides* **19** (5): 22-25.

Chari, M.S. and Patel, N.G. 1973. Occurrence of tingid bug on banana and its control. *Madras agric.* **60** (7): 623.

*Cheng, C.H. 1967. An observation of *S. typicus* on banana. *J. Taiwan agric. Res.***16** (2): 54-69.

*Corbett. 1929. Division of entomology, Annual report for 1928. *Malayan Agric. J.* 17(8): 261-267.

*Corbett. 1932. Insects of coconut in Malaya. *Rept. Agri. Sci.* FMS.**10**: 50-51.

*Distant, W.L. 1903. *The fauna of British India, including Ceylon and Burma, Rhynchota, Vol.II* (Heteroptera) Part IX. Taylor and Francis, London. p. 132.

*Distant, W.L. 1910. *The fauna of British India, including Ceylon and Burma, Rhynchots, Vol. V.* Taylor and Francis, London. p. 108.

*Fletcher, T.B. 1914. Some South Indian Insects. Government Press Madras. p. 484-485.

*Fletcher, T.B. 1920. Observations of *Stephanitis typicus* Distant, a pest of coconut palm. *Proc. Third Entomological Meeting Pusa.***12**: 263.

*Hoffman, 1935. Observations on a hesperid leafroller and lace bug, two pests of banana *Kwantung Longnam Sci. J.* 14 (4): 639-649.

*Holmes, F.O., Lal, S.B. and Shanta, P. 1965. Cowpea inoculation test for diagnosis of coconut wilt disease in India. *Pl. Prot. Bull.* 13 (2): 30-34.

Joseph, T., Shanta, P. and Lal, S.B. 1972. Role of *S. typicus* Distant in the spread of root (wilt) pathogen. *Indian J. agric. Sci.* 42 (5): 414-417.

*Korusiu and Chuyau. 1966. Ecological notes of *S. typicus* in Taiwan. *Pl. Prot. Bull.* 8 (2): 163-167.

Mathen, K. 1960. Observation on *Stephanitis typicus* Distant, a pest of coconut palm. *Indian Cocon. J.* 13: 8-25.

Mathen, K., Mathew, J. and Kurian, C. 1967. Seasonal abundance of the population of *Stephanitis typicus* Distant in the field of coconut palm. *Indian J. agric. Sci.* 38 (4): 644-653.

*Mathen, K., Sathiamma, B. and Kurian, C. 1967. Record of *Apollodotus praefectus* (Heteroptera: Miridae) predacious on *Stephanitis typicus* Distant (Heteropters: Tingidae); a pest of coconut palm. *Curr. Sci* 36 (2): 52.

Mathen, K., Mathew, J. and Kurian, C. 1969. Pattern of distribution of *Stephanitis typicus* Distant (Heteroptera: Tingidae) a pest of coconut palm on its host plant. *Indian J. agric. Sci.* 39 (1): 57-61.

Mathen, K., Sathiamma, B., Abraham, V.A., George, T.G. and Kurian, C. 1970. Studies on *Stethoconus praefectus* predacious on *S. typicus*. *Annual Report 1970*, CPCRI, Kasaragod. p. 120.

Mathen, K. and Kurian, C. 1972. Description, life history and habits of *Stethoconus praefectus* (Distant) Heteroptera: Miridae predacious on *S. typicus* Distant (Heteroptera: Tingidae), a pest of coconut palm. *Indian J. agric. Sci.* **42** (3): 255-262.

Mathen, K., Govindankutty, M.P. and Mathew, C. 1979. Nature and extent of damage to coconut as a result of feeding by *Stephanitis typicus* (Distant), Placrosym II. p. 466-473.

Mathen, K. and Rajan, P. 1983. Transmission of root (wilt) disease. Annual Report 1983. CPCRI, Kasaragod, pp. 8.

Mathen, K. 1985. Lace bug abundance in root (wilt) disease affected coconut palms, cause or effect. *J. Plant. Crops* **13** (1): 56-59.

Mathen, K. 1986. Comparative abundance of the tingid vector *S. typicus* in root (wilt) disease affected and healthy coconut palms in Kerala. Proceedings of the All India Symposiumin on Vector and Vector Borne Diseases, Trivandrum, 1982 : 29-33.

Mathen, K., Soloman, J.J., Rajan, P. and Geetha, L. 1987. Electron microscopic evidence on the role of *S. typicus* as a vector of coconut root (wilt) disease. *Curr. Sci.* **56** (23): 1239-1241.

Mathen, K., Nair, C.P.K., Gunashekharan, M., Govindankutty, M.P. and Soloman, J.J. 1988. Stylet course of lace bug *S. typicus* in coconut leaf. *Proceedings of the Indian Academy of Sciences, Animal Sciences* 97(6): 539-544.

Nagaraj, A.N. and Menon, K.P.V. 1956. Note on the etiology of the wilt (root) disease of coconut palms in Travancore-Cochin. *Indian Cocon. J.*9: 161-165.

Nirula, K.K. 1955. Investigations on the pests of coconut palm part 1. *Indian Cocon. J.* 8: 118-130.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research. pp. 97-138.

Patil, A.P., Thakur, S.G. and Mahalkar, P.R. 1988. Survey and seasonal incidence of pests of turmeric and ginger in western Maharastra. *Indian Cocoa Arecanut Spices J.* 12 (2): 47-48.

Pillai, G.B., Mathen, K., Cecil, R.S. and Abraham, J. 1982. Studies on epidemiology of coconut (wilt) disease, *Annual report 1982*, CPCRI, Kasaragod. p. 55.

Pillai, G.B. 1985. Studies on natural enemies of lace bug *S. typicus* (Dist). *Annual Report* 1985. CPCRI, Kasaragod. p. 107-108.

Pillai, G.B. and Sathiamma, B. 1986. Studies on natural enemies of the lace bug *S. typicus*. *Annual Report, 1986*, CPCRI, Kasaragod. p. 75-76.

Pillai, G.B. and Sathiamma, B. 1987. Studies of natural enemies of the lace bug *S. typicus*, *Annual Report 1987*, CPCRI, Kasaragod. p. 70.

Pillai, G.B., Sathiamma, B., Dangar, T.K. and Ramachandran, C.P. 1990. Biological control of pests of coconut - Studies on the natural enemies of the lace bug *S. typicus*, *Annual Report 1990*, CPCRI, Kasaragod. p. 96-97.

Pillai, G.B., Sathiamma, B., Dangar, T.K., Abraham, V.A. and Ramachandran, C.P. 1991. Natural enemies of lace bug *S. typicus* (Distant), *Annual Report, 1991*. CPCRI, Kasaragod. p. 72-73.

*Ramakrishnayyar, T.V. 1942. A nettle grub pest of banana plant in South India. *Indian J. Ent.* **4** (2): 171-172.

Shanta, P. and Menon, K.P.V. 1960. Cowpea (*Vigna sinensis* Endl.) an indicator plant for coconut wilt virus. *Virology* 12: 309-310.

Shanta, P., Menon, K.P.V. and Patchupillai, K. 1960. Aetiology of the wilt (root) disease: Investigations on its virological nature. *Indian Cocon. J.*13: 56-59.

Soloman, J.J., Govindankutty, M.P., Mathen, K., Rajan, P., Sathiamma, B., Sasikala, M., Rajagopal, V., Chempaka, B., Cecil, R., Amma, P.G.K., Srinivasan, N., Pillai, N.G. and Kochubabu 1984. Root wilt disease of coconut - involvement of Mycoplasma like organisms, *Annual Report 1984*, CPCRI, Kasaragod. p. 1.

Soloman, J.J., Govindankutty, M.P., Mathen, K., Rajan, P., Nair, C.P.R., Sasikala, M., Chempakam, B., Chowdappa, P. and Shukla, A.K. 1986. Role of MLO's in root (wilt) disease of coconut, *Annual Report 1986*, CPCRI, Kasaragod, p. 8.

*Takahashi, R. 1936. Food habits and habitats of the Formosan Psyllidae with notes on the peculiar food habits of some Formosan phytophagous insects. *Japanese Kantyii* 10 (6): 291-296.

*Tigvattanont, S. 1990. Studies on the bionomics and local distribution of some lace bugs. *Khanraen agric. J.* 18 (4): 200-212.

Vadivelu, S., Mohanasundaram, M. and Rao, P.V.S. 1975. Record of parasites and predators on some south Indian crop pests. *Indian J. Ent.* 37 (1): 100-101.

* Originals not seen

DISTRIBUTION OF COCONUT LACEWING BUG *Stephanitis typicus* Distant AND ITS NATURAL ENEMY COMPLEX AND ASSESSMENT OF BIOCONTROL POTENTIAL OF THE MAJOR NATURAL ENEMIES

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ABSTRACT OF A THESIS

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ABSTRACT

A study on the distribution of the coconut lacewing bug *Stephanitis typicus* and its natural enemy complex was carried out during the period 1991-92 at four selected root (wilt) prone districts of Kerala. The bio-control potential of the major identified natural enemies were also carried out during the same period.

The results revealed that the population of *S. typicus* showed a fluctuation throughout the year. The population was higher in he field during the dry seasons and it was at lower levels in rainy periods. The numbers of the pests increased from January onwards and recorded its maximum in March-April. The population started decreasing from May onwards and recorded the lowest level in June-July. From August the number of pest again started increasing and reached the second maximum in September-October. The level of population recorded was lowest in November-December.

Congregation of *S. typicus* was observed in higher numbers on the inner whorls of coconut crown. Compared to leaves of inner whorls, the number of pest were fewer in middle and outer whorls.

Natural enemy population was observed to remain stagnant throughout the year. Only a slight fluctuation was recorded in population of natural enemies, in accordance with the increased level of pest population. Generally a low level of natural enemy population was observed in the field throughout the study period.

Rearing of S. typicus in glasshouse condition on different host plants like coconut, turmeric and arrowroot showed the preference by the pest to the coconut plants. Compared to other host plants the multiplication and survival of the pest was more on coconut plants.

Among the natural enemies observed in the field, the mirid predator S. praefectus was recorded as the important one. Other natural enemies observed in the field included spiders and one pentatomid bug. It was noticed that the mirid predator consumed both adults and nymphs of the pest. But in the case of spiders they preferred adults of the pest to nymphs.