TAXONOMIC STUDIES OF LEAF AND PLANT HOPPERS ASSOCIATED WITH PADDY IN KERALA

BY

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DECLARATION

I hereby declare that this thesis entitled "Taxonomic studies of leaf and plant hoppers associated with paddy in Kerala" 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.

Vellanikkara,
12 - 4 -1984.

ABDULLA, K.

CERTIFICATE

Certified that this thesis, entitled "Taxonomic studies of leaf and plant hoppers associated with paddy in Kerala" is a record of research work done independently by Sri. ABDULLA, 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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Introduction

INTRODUCTION

Rice, the staple food of the people of Kerala, is grown in about 0.8 million ha, which is the largest area under a single crop. The pest problem of paddy was increasing in Kerala since the introduction of high yielding varieties, among which leaf and plant hoppers are more important. Many species of leaf and plant hoppers are found commonly in rice fields. Only a few of them are important pests of rice, but it is very difficult to distinguish these species from others. Some of the leaf and plant hoppers which were considered hitherto as minor pests has attained the status of major pests. Nilaparvata lugens (Stal) has been reported to be occurring as a serious pest of paddy in Kerala (Das et al., 1973) from 1973 onwards.

The common name, 'leaf hopper' is used to the insects belonging to the family Cicadellidae, and 'plant hopper' to the insects belonging to the family Delphacidae, Meenoplidae etc. of the super family of Fulgoroidea under Hemiptera. Delphacids are easily recognised by the presence of a large mobile spur (calcar) borne on the inner side of the apex of hind tibia, while cicadellids are recognised by the presence of rows of regular longitudinal spines on the hind tibia.

Leaf and plant hoppers damage rice plant by sucking plant sap and transmitting a number of virus diseases. Some of these diseases have been reported from Kerala also.

Even though a number of leaf and plant hoppers affecting paddy are present in Kerala, no systematic studies have so far been undertaken to get the correct identities of these insects. Hence a survey was conducted in two important paddy growing tracts of Kerala namely Palghat, and Trichur districts. The taxonomic studies were mainly based on the study of male genitalia and the morphological characters of head. The results of these studies are given in the following pages.

Review of literature

REVIEW OF LITERATURE

1. Taxonomical studies

Studies on the taxonomy of leaf and plant hoppers were very meagre till the middle of the present century.

Melichar (1903) was the pioneer worker in the field of oriental leaf and plant hoppers. An extensive study was made by Distant (1908) who monographed the family Jassidae in his work on Rhynoota in the "Fauna of British India" series. Fletcher (1914) reported the distribution of Tettigoniella spectra Distant and Nephotettix bipunctatus (Fabricius) in South India and also gave an account of the biology of these pests. Giffard (1921) stated that the use of colour as a specific character has led to synonymy on account of there sometimes being several colour forms in the same species. The occurrence of both brachypterous and macropterous forms in the same species made Pruthi (1925) to study the genitalia of Rhynoota which is a valuable contribution for their classification.

Pennah (1956) erected a new genus Sogatella under Chlorionn taking Liburnia furcifera (Horvath) as the type. In 1963 he made a detailed study of the Sogatella furcifera complex mainly based on the bodily proportions, viz., submedian length of vertex, length of basal compartment, width of the anterior margin of pronotal disc, length of

mesonotum and mesoscutellum, length of frons and width of postclypeal disc and also on the genitalic characters. He included the species under the complex into three distinct genera, viz., Matutinus Leach, Sogatella Fennah and Sogatodes Fennah. Ishihara (1964) proposed the new name Nephotettix impicticeps for the preoccupied N. (cicada) bivnctatus (Fabricius) and gave a key in which N. impicticeps, N. cincticeps (Uhler) and N. apicalis (Motschulsky) were differentiated by characters of the males. Fennah (1965) after comparing population samples from various localities with respective type specimens has shown that Sogatodes brasilensis (Muir) and S. oryzicola (Muir) are conspecific. Hence the name S. brasilensis was suppressed and made a synonym of S. oryzicola. Ishihara et al. (1966) described two new species of the genus Nephotettix viz., N. malayanus and N. parvus sp.n. Ghauri (1968) recorded that the genus Nephotettix in Africa and Madagascar has been represented by two species N. modulatus Melichar and N. afer sp.n. Both these species are widely distributed in Africa and Madagascar. Hoshida (1970) reported a red eyed form of the brown plant hopper, Nilaparvata lugens (Stal) from Japan. Mamman (1971) has given detailed description of fourty six Indian delphacids including nineteen new species.

Ghauri (1971) made a detailed study of seven known species and one subspecies of Nephotettix based on male genitalia and other morphological characters like colour, measurement of head, vertex, pronotum, scutellum, tegmen, commissure, total length etc. They are N. virescens (Distant), N. nigropictus (Stal), N. cincticeps (Uhl.), N. modulatus Mellichar, N. palavensis Ishihara and Kawase, N. parvus Ishihara and Kawase, N. afer Ghauri and N. nigropictus yapicola Linnavouri. N. symmetricus sp.n. was described as a new species from Srilanka. A comparison of holotypes showed that N. virescens described earlier as Selenocephalus belongs to Nephotettix and is conspecific with N. (Cicada) bipunctatus (Fabr.); this name is preoccupied and the next available is N. virescens, of which N. impicticeps Ishihara becomes a synonym. The types of N. apicalis (Motsch.) and Pediopsis nigromaculata Motsch, which was synonymised with it was destroyed. N. nigropictus replaces N. apicalis Auct; N. yapicola Linnavouri becomes a subspecies of N. nigropictus.

Usha et al. (1979) studied the hybrid specimens between N. virescens and N. nigropictus and described the characters in detail. Kalode et al. (1979) reported the occurrence of biotypes of brown plant hopper causing different reactions to IR 26 in different areas. Gosh (1980) observed a 'blue form' of N. virescens Distant at Hyderabad. Sato et al. (1981) reported biotype variations in N. cincticeps (Uhler).

Viraktamath (1983) published a key to the economically important species of cicadellidae found in India.

2. Outbreaks of leaf and plant hoppers

Infestation of leaf and plant hoppers on paddy was reported from very early days from many parts of the world. Few of them considered previously as minor pests have now acquired the status of major pests of rice in most of the rice growing tracts of the world.

Fletcher (1913) reported the occurrence of Tettigoniella spectra (Dist.) and Nephotettix bipunctatus (Fabricius) in paddy fields of South India. Hutson (1921 & 1922) recorded Nilaparvata greeni Dist., Typhlocyba subrufa Motsch, Nephotettix bipunctatus (Fabricius) and Tettigoniella spectra Distant as pests of rice in Srilanka. Twenty three species of Jassids and Fulgorids were identified as injurious to rice crops in Korea by Okamoto (1924), of which Nephotettix apicalis (Motsch.) var. cincticeps (Uhl.), Liburnia oryzae Mats; and L. furcifera (Horv.) are the most important species. Corbett (1926) reported the outbreak of N. bipunctatus (Fabricius) and Sogata pallescens Dist. in rice in Malayasia. Hutson (1933) recorded the occurrence of Sogata furcifera (Horv) and Nilaparvata lugens (Stal) on rice in Srilanka.

Rao (1950) reported the outbreak of N. lugens from

Tenali area of Guntur district in 1927, from the delta areas of East and West Godavari in 1935 and again in 1942. An outbreak of Chloriona (Sogata) furcifera (Horv.) was reported on rice from Jabalpur district of Madhya Pradesh in 1958 (Anonymous, 1960). Suenaga et al. (1958) made a survey of paddy pests in Japan in which they recorded fifty eight species of leaf and plant hoppers, of which ten species were serious pests of rice plant. Bajpai (1964) recorded a severe outbreak of Sogatella furcifera (Horv.) in Madhya Pradesh. Mokrotovarov (1965) reported Nephotettix apicalis (Motsch.) causing heavy losses to young rice plants in Indonesia. Atwal et al. (1967) recorded an outbreak of Sogatella furcifera (Horv.) in Punjab and studied the biology and control of this pest. In transmission studies of virus diseases of rice, King (1968) reported 25 species of leaf and plant hoppers on rice in Thailand, among which N. cincticeps (Uhl.), N. apicalis (nigropictus) (Motsch.); Inazuma (Recilia) dorsalis (Motsch.); Thaia oryzivora Ghauri; Kolla mimica Dist., Macrosteles spp, Nilaparvata lugens (Stal); Sogatella furcifera (Horv.); Nisia atrovenosa (Leth.). Delphacodes spp, Balcluthe spp, and Sogatella formosella (Mats.) were considered as most important pests of paddy. Grist and Lever (1968) studied the distribution of S. furcifera (Horv.) and N. lugens (Stal) and found that they are serious pests of rice in India. Chatterjee (1971)

reported a severe outbreak of Sogatella furcifera (Horv.) in upland autumn rice in two northern districts of West Bengal. In a survey conducted at Java, Soehardjan (1973) presented a list of leaf and plant hoppers in which Thaia oryzivora Ghauri , Recilia dorsalis (Motsch.), Nephotettix spp., Sogatella furcifera (Horv.) and Nilaparvata lugens (Stal) are important pests of rice.

Pawar et al. (1976) reported the occurrence of the following pests viz., N. nigropictus (Stal), N. virescens (Dist.), Recilia dorsalis (Motsch.), Exitianus indicus (Dist.), Tettigella spectra (Dist.),Nilaparvata lugens (Stal), Sogatella furcifera (Horv.), Oliarus caudatus (Blk.), Nisia atrovenosa (Leth.) and Yasumatsuus minicus (Dist.) associated with rice in Himachal Pradesh. Channa Basavanna et al. (1976) reported an outbreak of N. lugens (Stal) on rice in Karnataka. Prakasa Rao et al. (1976) observed severe infestation of N. lugens in East Godavari district causing hopper burn in an estimated area of 200 ha. Natarajan (1978) recorded outbreaks of N. lugens (Stal) in Madurai in Tamil Nadu in 1973 and 1979. First report of the occurrence of S. furcifera (Horv.) in Pakistan was made by Mahar et al. (1979) at Rice Research Station, Dokri. Verma et al. (1979) reported regular infestation of brown plant hopper and white backed plant hopper in Uttar Pradesh from 1969 onwards excepting 1970 when the crop was free from the attack of brown plant hopper.

Claridge et al. (1981) recorded over 50 species of leaf and plant hoppers from rice fields of South East Asia.

Bishnu et al. (1983) noticed that even though S. furcifera (Horv.) was considered as a minor pest of rice in Nepal, a severe infestation causing hopper burn was occurred in Kathmandu, Bhaktapur and Lalithpur during 1982 wet season.

3. Biological and ecological studies

1. Cicadellidae

Misra (1920) gave a general account of the biology of Nephotettix bipunctatus (Fabr.). Eggs hatch in 4 to 6 days and the nymphal stage lasts from 13 to 21 days comprising five moults. Abalose (1939) described the biology of N. bipunctatus (Fabr.) and N. apicalis (Motsch.) in detail. In Philippines they are generally abundant during August and October. They attack the plants in all stages of growth, feeding on the leaves and leaf sheaths, as a result of which the tips of the older leaves dry, yellow spots appear on the midrib and the leaf sheaths and plant become stunted. The eggs are deposited in rows under the epidermis of leaf-sheaths of young plants and hatch in 5 to 10 days, the 5 nymphal instars occupy a total of 13 to 19 days. Oviposition begins 2 to 3 days after the emergence of adults.

Misra et al. (1968) conducted detailed anatomical studies of the ovipositional sites of different leaf hoppers.

Nephotettix spp., Recilia dorsalis (Motsch.), Tettigella spectra (Dist.) and Kolla mimica Dist. oviposited in the bulliform cells near the midrib of the leaf blade. It was observed that the egg mass laid in the wings of leaf sheath are less well protected from insecticide sprays than those in the midrib. Chen (1970) reported that the complete life cycle of Nephotettix impicticeps lasted about 70 to 80 days in summer and 120 to 130 days in winter.

Cheng et al. (1971) conducted laboratory studies on the bionomics of Nephotettix virescens (Dist.) in Philippines. These studies have shown that 29° and 33°C were the best temperatures for the development of the eggs, nymphs and adults. At 20°C the rate of growth of eggs and nymphs slowed down considerably and there was a significant reduction in the number of eggs laid. At 35°C development was somewhat accelerated but the adults lived for a shorter period and the females laid fewer eggs than at other temperatures tested. Unfertilized females laid sterile eggs at random on leaf sheaths, but females that had paired inserted their eggs into the tissues at the edges of the leaf sheaths. More than 60% of the eggs were laid in the outer most leaf sheaths, mostly near the base of plants. The nymphs and adults were most abundant on the leaf blades. Population increased rapidly on older plants than young seedlings.

Wan (1972) found that among the species of homopterans recorded on rice in Borneo more than 90% constituted Nephotettix virescens, N. nigropictus, Tettigella spectra, and Recilia dorsalis. A significant correlation was noted between water soluble protein nitrogen in rice plant and population of hoppers in the fields.

Basu et al. (1976) found that N. virescens can overwinter in the grass Polypogon monspeliensis (L) besides rice plant. Nymphal stages of the leaf hopper was found to be greatly lengthened during winter, insect could withstand long periods of fasting on moist soil indicating reduced metabolism during winter. The longivity of females was found to be more than that of males. Garg (1980) observed that prevailing agroclimatic conditions were the most important factors in the initial appearance and subsequent population build up of rice pests viz., N. virescens and T. spectra. Weekly averages of 28.59°C, 69.55 R.H., 8.18 hours of sunshine and 0 to 71 millimeter rain were found to favour the population build up of these pests.

2. Delphacidae

Miller et al. (1930) studied the ecology of Sogatella furcifera (Horvath) and found that later nymphal instars inclined to feed higher upon the rice plants in the early morning and to descend as the sun becomes powerful. In Japan, Esaki et al. (1932) reported 5 generations of Nilaparvata

lugens (Stal) in a year and the total life cycle was completed in 13 to 22 days, brachypterous forms were common in both sexes. Caresche (1933) noted that nymphs and adults of N. lugens usually remains in the lower parts of the plant near the water level feeding on the sap and secreting honeydew and they seldom leave a plant until it is completely exhausted. Lever (1939) observed that the yellowing of the leaves due to infestation of S. furcifera was invariably worst in areas where the rice was permanently flooded or had experienced heavy or persistent rain.

Kisimoto (1956) found that low density with optimum conditions of food supply during larval development was necessary for the appearance of the brachypterous females whereas optimal density under favourable conditions of food supply produced brachypterous males. Wilting of the host plant, over crowding and contamination due to crowding have the effect of producing the macropterous forms and this effect was followed by lengthening of the development period of the larvae subject to these conditions. Miyake et al. (1961) found that the wing form of S. furcifera was determined by environmental factors during nymphal development. Nymphs reared at high population density and feed on grasses (Poa annua) gave rise to macropterous adults. Hinckley (1963) observed that the factors influencing the outbreak

of brown plant hoppers include the amount of rainfall, type of cultivation, age of rice crop, species composition of the plant hopper populations and the relative abundance of the parasites. Populations of delphacids are apt to reach the damaging levels on transplanted rice growing in pools of standing water after a dry period. Kisimoto (1965) observed that macropterous forms are better adapted to unfavourable conditions and brachypterous forms are adapted to rapid multiplication under favourable conditions. Atwal et al. (1967) studied the biology of S. furcifera and found that during August-September the egg and nymphal stages lasted 3.4 to 4.6 days and 8.9 to 13.1 days respectively. In the laboratory both macropterous and brachypterous adult females occurred, the former living for 1 to 9 days and the latter 5 to 11 days, the adult males lived for 1 to 2 days. Misra et al. (1968) conducted detailed anatomical studies of the ovipositional sites of different plant hoppers. They found that S. furcifera and N. lugens laid their eggs in masses in the midrib of both leaf sheath and leaf blades, placing them in the air cavities of the midrib.

Rae et al. (1970) found that N. lugens underwent optimum development at 25°C and 29°C, 32°C was found to be detrimental to all life stages. Saxena et al. (1981) reported that changes in the physiological status of rice plant had a profound effect on wing morphism in N. lugens.

Significant increase in the macroptery of hopper progenies reared on senescent or hopper burned plants occurred mainly because of general decline in the hosts nutritional status and allelochemic factors. Starvation of young nymphs on nutritionally depleted hosts probably inhibits the secretion of juvenile hormone by the Corpus allatum, suppressing brachyptery and expressing macroptery. Also any juvenilising effect of the hosts allelochemics would tend to dissipiate with the host's senescence.

4. Leaf and plant hoppers as vectors of rice diseases

Leaf and plant hoppers play a major role in the transmission of virus diseases of rice. In the survey report of Commonwealth Mycological Institute (1972) a list of rice diseases transmitted by leaf and plant hoppers is given. The important rice diseases and their vectors are presented below.

Disease	Vectors
1. Dwarf	Nephotettix cincticeps (Uhl.)
	N. nigropictus (Stal) apicalis Auct.
	Recilia dorsalis (Motsch.)
2. Stripe	Laodelphax striatella (Fall.)
	Unkanodes sapporonus (Mats.)
3. Yellow dwarf	Nephotettix virescens (Dist.)
	N. cincticeps (Uhl.)

4. Black streaked dwarf	L. striatella (Fall.)
	U. sapporonus (Mats.)
5. Hoja blanca	Sogatodes oryzicola (Muir)
	S. cubanus (Crawford)
6. Transitory yellowing	N. nigropictus (Stal)
	N. cincticeps (Uhl.)
7. Tungro	N. virescens (Dist.)
	N. nigropictus (Stal)
	R. dorsalis (Motsch.)
8. Grassy stunt	Nilaparvata lugens (Stal)
9. Orange leaf	R. dorsalis (Motsch.)

Satomi et al. (1975) reported N. nigropictus, N. virescens and N. cincticeps as vectors of rice waika virus. Adults and nymphs of N. lugens transmitting rice ragged stunt virus, was reported by Ling et al. (1977). Putta et al. (1980) recorded a new virus disease of rice viz., Gall dwarf producing gall like swellings on leaf blades and sheaths which was transmitted in a persistent manner by R. dorsalis and N. nigropictus.

5. Natural enemies

Natural enemies of leaf and plant hoppers include parasitic and predaceous insects, spiders, nematodes and fungi. Important parasitic and predaceous insects include members of the order Hymenoptera, Hemiptera and Coleoptera.

Pagden (1934) reported Paranagrus optabilis Perk; a mymarid, parasatising Sogata furcifera (Horv.) which parasatised about 70% of the eggs examined. Esaki et al. (1936) recorded the Dryinids Echthrodelphax bicolor Esaki and Hashimoto. Haplogonatopus japonicus Esaki and Hashimoto and Pseudogonatopus flavifemur Esaki and Hashimoto parasatising Nilaparvata oryzae. He also noted a fungus Entomophthora delphacis infecting N. oryzae, N. bipunctatus and N. cincticeps.

Patel (1968) recorded a pteromalid endoparasitic to the nymphs and adults of Sogatella furcifera at Raipur. Abraham et al. (1973) recorded Coccinella arcuata Fabricius as a predator on the nymphs of Nilaparvata lugens. In 1974 they studied the predatory potential of the beetle in detail. Pawar (1975) reported a mirid bug Cyrtorhinus lividipennis (Reuter) as a predator of the eggs and nymphs of brown plant hoppers and green leaf hoppers in Himachal pradesh. Nayak et al. (1979) observed Beauveria bassiana (Bals) attacking nymphs and adults of green leaf hoppers N. nigropictus (Stal) and N. virescens (Dist.).

Pophaly et al. (1979) studied the biology and predation of Cyrtorhinus lividipennis. They found that the predator completed the life cycle on eggs and early nymphal stages of N. lugens, S. furcifera, N. virescens and N. nigropictus. Under field conditions the predator prey ratio of 1:4 was found to control N. lugens.

6. Studies conducted on leaf and plant hoppers in Kerala

Researches conducted on the leaf and plant hoppers are very meagre in Kerala. A perusal of literature reveals that very little work has been done on this group of insect pests in the State. Most of the studies in this regard was related to brown plant hopper Nilaparvata lugens, the notorious pest of paddy, even though other hoppers have got the potentiality of becoming major pests.

Gopalakrishnan et al. (1973) reported the occurrence of grassy stunt transmitted by Nilaparvata lugens in an epidemic form in the Kole and Kuttanad areas. In the same year they also reported the occurrence of 'Tungro virus' in Kodakara block of Trichur district, and Angamali block of Ernakulam district, the vectors of which are Nephotettix virescens, N. nigropictus and Recilia dorsalis.

Das et al. (1973) reported a severe infestation of Nilaparvata lugens (Stal) in southern districts of Kerala. In many fields the damage was so heavy that the farmers were forced to abandon the crop. All stages of the pest cluster around the tiller of each clump, just above the water level. Their preference to remain on the inner tillers of the clump rendered them inaccessible to insecticides applied in routine schedule. Paddy in all stages was found susceptible to the leaf hopper attacks. Improved varieties particularly when given a close planting and heavy doses of nitrogenous

fertilizers suffered most from this pest.

Abraham et al. (1973) reported Coccinella arcuata Fabricius predaceous on the nymphs of Nilaparvata lugens. Adult beetles feed on the first, second and third instar nymphs of Nilaparvata lugens and the average consumptions being 20 per day. Mammen et al. (1974) published a key for the identification of Indian delphacids which include important pests of paddy like N. lugens and Sogatella furcifera. Abraham et al. (1974) studied the predatory potential of the lady bird beetle Coccinella arcuata Fabricius. They found that on an average the freshly emerging first instar grub ate first and second instar nymphs of N. lugens at 15 per day. The second, third and fourth larval instars and the adults consumed all nymphal stages of the host at 18, 25, 27 and 29 per day respectively. The adult occasionally feed on adult hoppers. The predatory potential was maximum during February-March, occurring on the punja rice crop.

Malinakumari et al. (1975) studied the biology of N. lugens in detail. They found that mating commences from the day of emergence, generally during night time, rarely during day time. Oviposition starts from second day of emergence and extends upto four days. Eggs are thrust within the tissues generally in the mid region of the outer leaf sheath in rows of 2 to 12 eggs and with the operculum projecting out. Number of eggs laid by the female ranges

from 151 to 305, average being 234. Egg laying period varied from 10 to 28 days, incubation period is 8.1 days. Eggs hatch during the early hours of the day. Nymphal period ranges from 2 to 3 days, 2 to 4 days, 2 to 4 days and 2 to 4 days for the first, second, third and fourth instars respectively.

Das et al. (1977) found that higher levels of water in rice fields is conducive to the multiplication of brown plant hopper. Draining the field immediately after the initial observation of the pest and maintaining irrigation only to field capacity may inhibit the multiplication of N. lugens and avert the possible emergence of the insect as a serious pest.

Nair (1978) gave a detailed account of Nilaparvata lugens, Nephotettix virescens, N. nigropictus and Sogatella furcifera as pests of paddy in Kerala.

Nair et al. (1980) recorded two population peaks of brown plant hopper in paddy tracts of Kuttanad, major peak during January-March and a minor one during August-September for the second crop. Correlation studies revealed that the hopper population was significantly influenced by climatic factors. Rainfall in association with relative humidity and maximum temperature played a decisive role in regulating the population build up of Nilaparvata lugens.

Baby et al. (1981) found carbaryl, monocrotophos, dichlorovos, quinalphos, fenthion, phosalon, fenitrothion and dichlorovos are equally effective in controlling N. lugens.

Materials and methods

MATERIALS AND METHODS

1. Materials

1.1. Sources of insect material

Leaf and plant hoppers for the study were collected from paddy fields of Kole, Pattikkad and Mannuthy in Trichur district and Pattambi of Palghat district.

1.2. Equipments

1.2.a. Hand net (Fig.II): A convenient hand net was prepared for this purpose. The net is easy to carry. All it's parts can be dismantled and placed in a handbag. It consists of the following parts.

(i) Handle: This is of a light but strong bamboo rod about 1 meter in length, and 2.5 centimeter in diameter. The head of a bolt is inserted at one end of the handle and tightly fixed. The threaded end of the bolt is kept free and provided with a fly nut.

(ii) Rim: It is made of a fairly strong wire which is bent into two semicircular shaped pieces having 30 cm diameter and with a small loop at either end. Loop at one end of both the semicirdircular wires are inserted into the bolt and fixed with the nut and the other end of the wires are joined together by interlocking the loops. The two semicircular wires together will serve as the rim for the net. By this nut and bolt arrangement, the hand net can be folded easily

when not in use.

(iii) Bag: It is made of fine mesh net cloth stiched on the circular rim.

1.2.b. Aspirator. (Fig.I): An aspirator was made with a wide mouthed specimen tube, closed with a rubber cork having two holes through which two glass tubes of about 0.5 cm diameter were inserted. Both tubes were bent at right angles. One tube was inserted deeper and the other one just below the cork with the end inside the tube covered by cloth and a rubber tubing was attached to the other end. By sucking out the air through the rubber tubing the insects could be drawn into the wide tube through the other tube from a sweeping net. The muslin cover at the other end of the sucking tube retains the insects in the aspirator.

1.2.c. Microneedles: A strip of paper about 7.5 cm x 3.75 cm is cut with edges straight to form a rectangular bit. The strip is rolled lengthwise very tightly and the outer edges of it is glued. To it's pointed end a microneedle (No.20 entomological pin) is introduced and fixed by 'quick fix' (Menon, 1965).

1.2.d. Glasswares and chemicals: These include 10% KOH, acetic acid, acid fuchsin, carbolxylol, slides, coverslips, store boxes, brass coated pins, formalin, naphthelene balls etc.

FIG. I. ASPIRATOR.

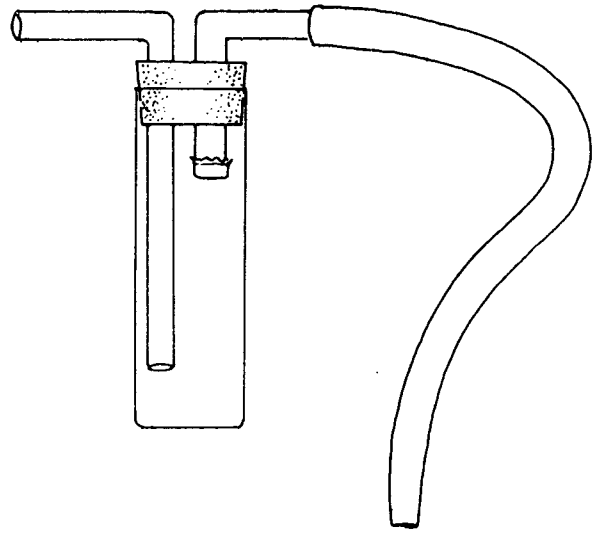


FIG. II. HAND NET.

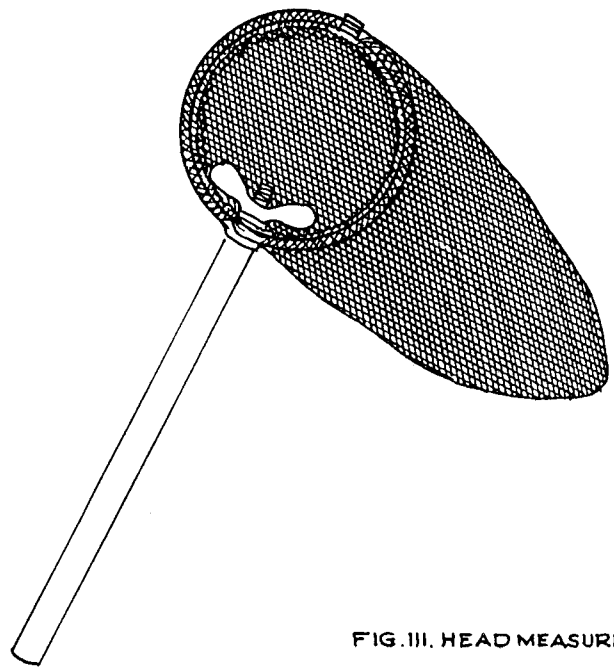
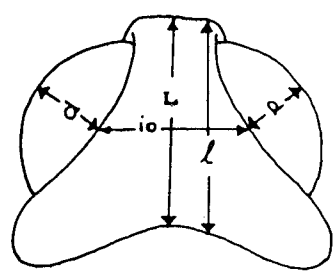


FIG. III. HEAD MEASURMENTS.



2. Methods

2.1. Collection of insects

Collections were made by sweeping rice crop during virippu and mundakan seasons from Pattambi, Pattikkad and Mannuthy and during Mundakan season from Kole lands in the year 1982-1983. Weekly collections of insects were made with the hand net for the entire seasons from transplanting upto harvest. In order to get an idea about the population fluctuations of different species, fixed number of sweeps were taken from the same field for every week. Ten strokes along one border and ten strokes diagonally were carried out for the first week. The border and diagonal directions were changed for the successive weeks. From the sweepings, insects were collected with the help of aspirator and taken to the laboratory.

2.2. Killing

In the laboratory the aspirator was held with the bottom towards light near a glass window. When the insects concentrated in the bottom of the aspirator, the cork with the tubes was gently removed and a cork without holes was fitted. Then a strip of paper dipped in benzene was introduced into the aspirator tube and the paper was held in position by trapping it's end in between the cork and the tube. The tube was kept vertically a few minutes and all the dead insects were collected at the bottom of the tube without being wetted with benzene. Care was taken to use only just

enough benzene on the paper strip in order to avoid direct contact of benzene with the insect and consequent discoloration.

The specimens could also be killed by putting them in special killing tubes prepared by keeping a wad of cotton wool soaked in benzene from which the excess fluid is squeezed out and tucked down to the bottom of the specimen tube and padded with discs of white blotting paper.

2.3. Preservation

Dead specimens were well dried by keeping in a drying chamber using a 60 watt bulb for 24 hours. This helped to keep the specimens free from fungal attack throughout the study. Collections from each field for each week were separately preserved in homeopathic vials in which FDB was put and collection data were recorded on each vial.

Introducing paper strips soaked in formalin into the vials was also found to be effective in preventing fungal attack, but it decolourised the specimens.

2.4. Morphotaxonomic studies

After completing collections, insects in all vials were sorted out, number of specimens collected in each week were noted, sexes separated and each species was preserved in separate homeopathic vials. These vials were serially numbered and the collection data were also noted. Few specimens from these vials were mounted for detailed studies.

2.4.a. Mounting for gross studies: Tag mounts of specimens were made for studies on the general form and colouration. Triangular paper tags were cut out from the cards by means of scissors and pinned with ordinary brass coated pins. At the conical point of the tag a single specimen was gummed with insect gum prepared by diluting 'Quick fix' with amyl acetate. The specimen was stuck to the paper point with the right mesopleura so that the head was turned to left and the tip of the abdomen to the right. This orientation of specimens was found very useful for the examination of all desired parts in situ and also to remove the abdomen for further studies, if desired with great ease. Each tagged specimen was labelled with collection data.

2.4.b. Detailed studies: For the detailed study of the male genitalia, slide mounts were prepared. For detaching the parts microneedles made out of No.20 entomological pins were used.

Tip of the abdomen was gently detached from the tagged specimen and was dropped in a test tube with a small quantity of 10% potassium hydroxide solution and gently boiled over a mild flame for about a minute or two. The time required for this treatment was adjusted in accordance with the sclerotisation of the parts. Fresh specimens took less time than dry preserved ones. On cooling the boiled material was transferred to a cavity block containing glacial acetic acid.

After sometime the material was again transferred to another cavity block containing glacial acetic acid with a trace of acid fuchsin. By this method it was found that the alkali could be neutralized, staining quickened and part of the clearing accomplished. All these could be completed in about ten to fifteen minutes. When well stained, the specimen was transferred to another cavity block containing carbol-xylol (carbolic acid and xylol mixed in the ratio of 1:3). Complete clearing was found to be accomplished in this within five to ten minutes.

Dissection was done under a stereoscopic binocular microscope. For dissecting out the genitalia, the cleared and stained material was transferred into a drop of canada balsam on the slide. The genital capsule was gently separated from the rest of the abdomen by means of micro needles. Using microneedles the internal genitalia complex are pushed outward without harming the pygofer. Utmost care was taken to avoid crushing or smothering of parts during manipulation and handling. Pygofer was arranged in the centre of the canada balsam. Then all other parts were also arranged in the canada balsam. In order to prevent the pressing of the pygofer small pieces of cover slips were placed in three or four corners of the canada balsam one above the other, so as to have the same thickness of the pygofer. Then a cover slip was gently placed over the pygofer. The slides were labelled

together with the collection data and kept in the slide tray for drying. By this method the whole procedure of mounting was found to take less than an hour.

2.4.c. Morphometric studies: While studying the taxonomy of psocoptera, New (1977) pointed out that head measurements, 'I.O/D' and P.O. are sometimes used for specific separations and he has given two methods for measuring I.O/D.

(i) Pearman's method (Pearman, 1974). The ratio of the shortest interocular distance (I.O) to the greatest horizontal eye diameter (D) as seen from the front (facial aspect) of the head.

(ii) Badonnets method (Bal, 1943). The ratio of the shortest interocular distance (I.O) to the length of the longest axis of the eye (D) as seen from the top (dorsal aspect) of the head. P.D is D/d (Badonnet), the ratio of the shorter eye axis (d) to the greatest eye axis (D) from the dorsal aspect. In view of this it was decided to study more or less the same head measurements for the segregation of species and sexes in the hoppers under study. However measurements were taken in a slightly different way in dorsal view as shown in the figure III. This is slightly different from the measurements suggested by the previous workers mentioned above. The change has been introduced for the sake of easy manipulation.

2.5. Presentation

2.5.a. Sketching: The slides were carefully studied for all details by means of high magnification compound microscope. Drawings were made by the author with the help of a mirror camera lucida.

2.5.b. Legends to the illustrations

a. Pygofer
b. Subgenital plates
c. Paramere
d. Basal plate
e. Aedeagus
f. Anal segment

2.5.c. Magnification: There is no uniformity regarding magnification and different magnifications are used for different parts of the same species. Therefore scales of magnifications are given separately near each figure. The line on the side of the figures shows the scale. All lines drawn are 100 microns.

Results

RESULTS

The author could procure leaf and plant hoppers belonging to three different families viz., Cicadellidae, Delphacidae and Meenoplidae from different paddy fields in Trichur and Palghat districts. These families were segregated by using the key given by Borrer et al. (1976). The following species of leaf and plant hoppers associated with paddy were collected.

Family: Cicadellidae

1. Nephotettix virescens (Dist.)
2. N. nigropictus (Stal)
3. Recilia dorsalis (Mots.)
4. Tettigella spectra (Dist.)
5. Exitianus indicus (Dist.)

Family: Delphacidae

1. Nilaparvata lugens (Stal)
2. Sogatella furcifera (Horv.)
3. Matutinus pusanus (Dist.)

Family: Meenoplidae

1. Nisia nervosa (Motsch.)

1. Family. Cicadellidae

Insects belonging to four genera of this family were obtained. These include Nephotettix, Tettigella, Recilia and Exitianus. The species coming under the first three genera

were identified with the help of the key provided by Viraktmath (1983) and that of Exitinus by comparison with the identified specimen available in the collections of College of Horticulture.

The colouration and genitalic characters of these specimens were studied.

1.1. Nephotettix virescens (Distant)

Colouration.

Male: Head, pronotum and scutellum green without any black markings. Tegmen with a discal spot which does not touch claval suture; apical third of tegmen black. Inner margins of clavus usually unmarked but in some cases finely black.

Female: Head, pronotum and scutellum green without any black markings. Tegmen without discal spot, entirely green or apical one third black, inner margin of clavus unmarked.

Male genitalia (Fig. IV)

Pygofer: Disto-ventral and disto-dorsal corners round with a single long spine and four smaller spines laterally.

Subgenital plates: Wider at base and narrowed at apex, uniseriate setae submarginally located.

Basal plate: 'Y' shaped with arms close to each other.

Paramere: Internal process straight, elongate with apex obliquely entire.

Aedeagus: Apex as wide as immediately proceeding part when viewed laterally. Dorsal longitudinal carinae with five pairs of spines located in the middle of aedeagal shaft, spines

are well separated, shaft more or less constricted in middle in ventral view.

Materials examined: Several examples from Mannuthy, Pattambi, Kole and Pattikkad.

1.2. Nephotettix nigropictus (Stal)

Colouration.

Male: Vertex with marginal and submarginal black bands, pronotum with anterior marginal black band, clavus with basal and inner marginal black bands. Large discal spot touching claval suture; apical third of tegmen black.

Female: Vertex with marginal and submarginal black bands, pronotum with anterior marginal black band, clavus with basal and inner marginal black bands, discal spot large, apical third of tegmen black.

Male genitalia (Fig. V)

Pygofer: Disto-dorsal corner rounded with a single long spine and four smaller spines laterally; disto-ventral corner with a small lobe.

Subgenital plates: Short triangular, uniseriate setae submarginal.

Basal plate: 'Y' shaped with arms not close to each other.

Paramere: Internal process straight elongated; apical margin slightly convex.

Aedeagus: Extreme apex of aedeagus in lateral view swollen, wider than the immediately preceeding part. Dorsal

Fig. IV.

Male genitalia of Nephotettix virescens (Dist.)

Fig. V.

Male genitalia of Nephotettix nigropictus (Stal)

FIG. IV. *Nephotettix virescens* (Dist)

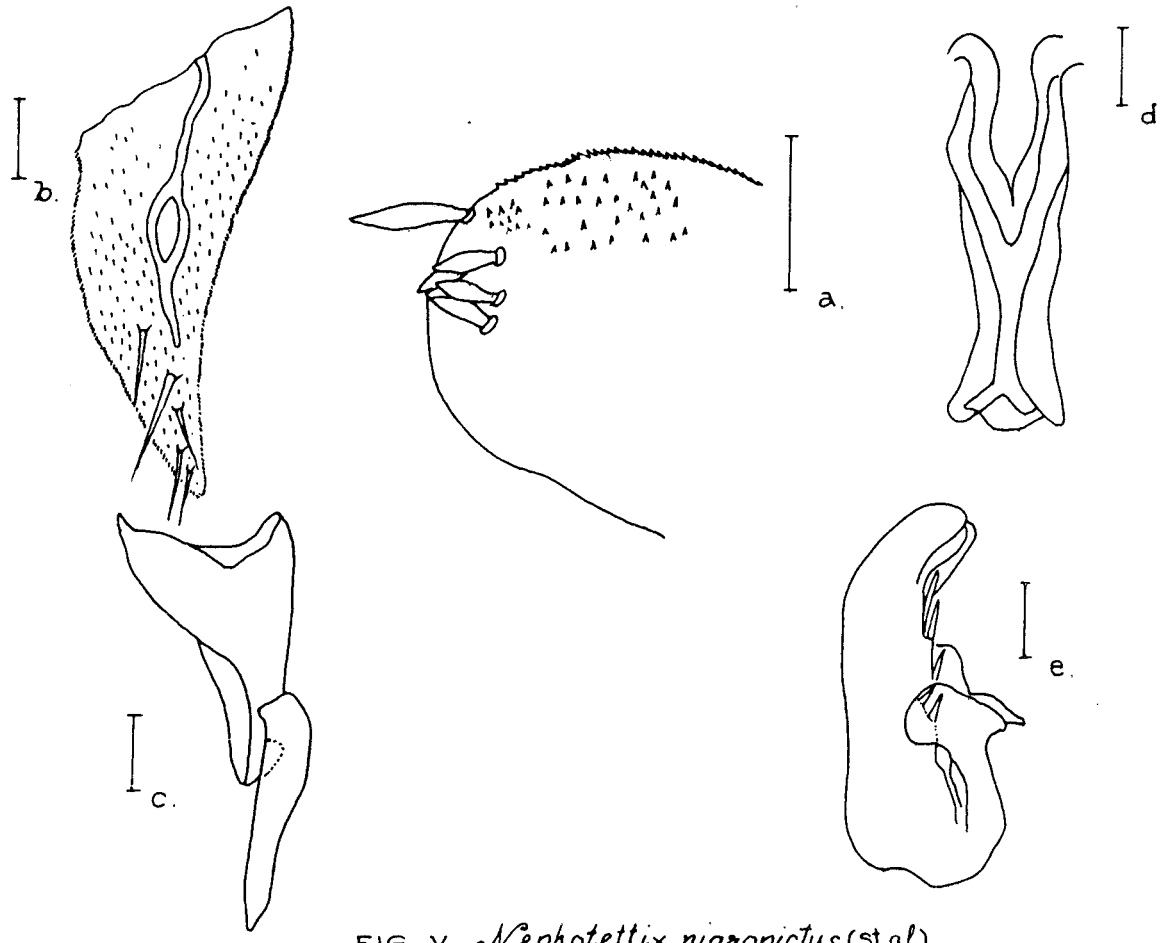
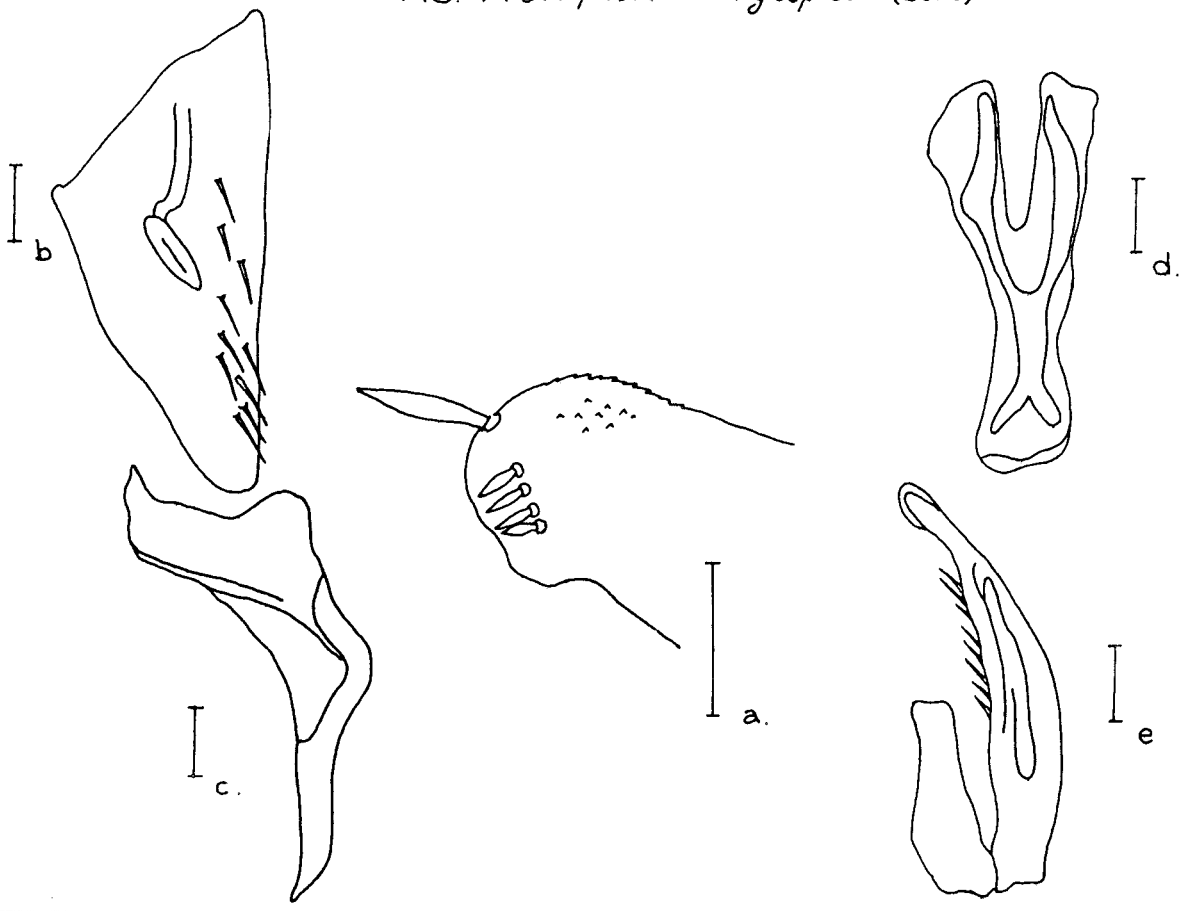


FIG. V. *Nephotettix nigropictus* (Stal)



longitudinal carinae with eight pairs of closely located spine; shaft in ventral aspect almost straight.

Materials examined: Specimens collected from Mannuthy, Pattambi and Kole.

Apart from these two species of Nephotettix, four specimens belonging to the same genus were obtained but whose specific identity is doubtful. A detailed comparative study of these specimens were not possible for want of sufficient specimens.

Of these two are males and two are females. Perhaps these may be hybridised specimens. Colouration and genitalia of these two males and colouration of females were studied and described.

Specimen No.1. (Male)

Colouration: Vertex with marginal and submarginal black band. Pronotum with a fine black band, scutellum without marking. Apical third of tegmen black, inner margin of clavus not black, discal spot does not touch claval suture.

Male genitalia (Fig. VI)

Pygofer: Disto-dorsal corner round with long spine and three small spines laterally, disto-ventral corner with a small lobe.

Subgenital plates: Short, triangular; uniseriate setae submarginal.

Basal plate: 'Y' shaped with arms not close to each

other.

Paramere: Internal process straight, elongate, apical margin convex.

Aedeagus: Apex of aedeagus shaft wider than the immediately preceeding part in lateral view; dorsal longitudinal carinae with six pairs of spines, first four spines closely located and apical two well separated.

Materials examined: One specimen from Mannuthy

Specimen No.2. (Male)

Colouration: Vertex with marginal and submarginal black bands. Anterior margin of pronotum with a pale black band; basal and inner margin of clavus colourless, tegmen entirely green without discal spot.

Male genitalia (Fig. VII)

Pygofer: Disto-dorsal corner round with a long spine, disto-ventral corner slightly pointed, disto-lateral spines three in number.

Subgenital plates: Triangular, uniseriate setae submarginal.

Basal plate: 'Y' shaped, arms coming close to each other.

Paramere: Internal process straight.

Aedeagus: Extreme apex of shaft as wide as immediately preceeding part when viewed laterally, dorsal longitudinal

Fig. VI.

Male genitalia of Specimen No. (1)

Fig. VII.

Male genitalia of Specimen No. (2)

FIG. VI. SPECIMEN No. (1).

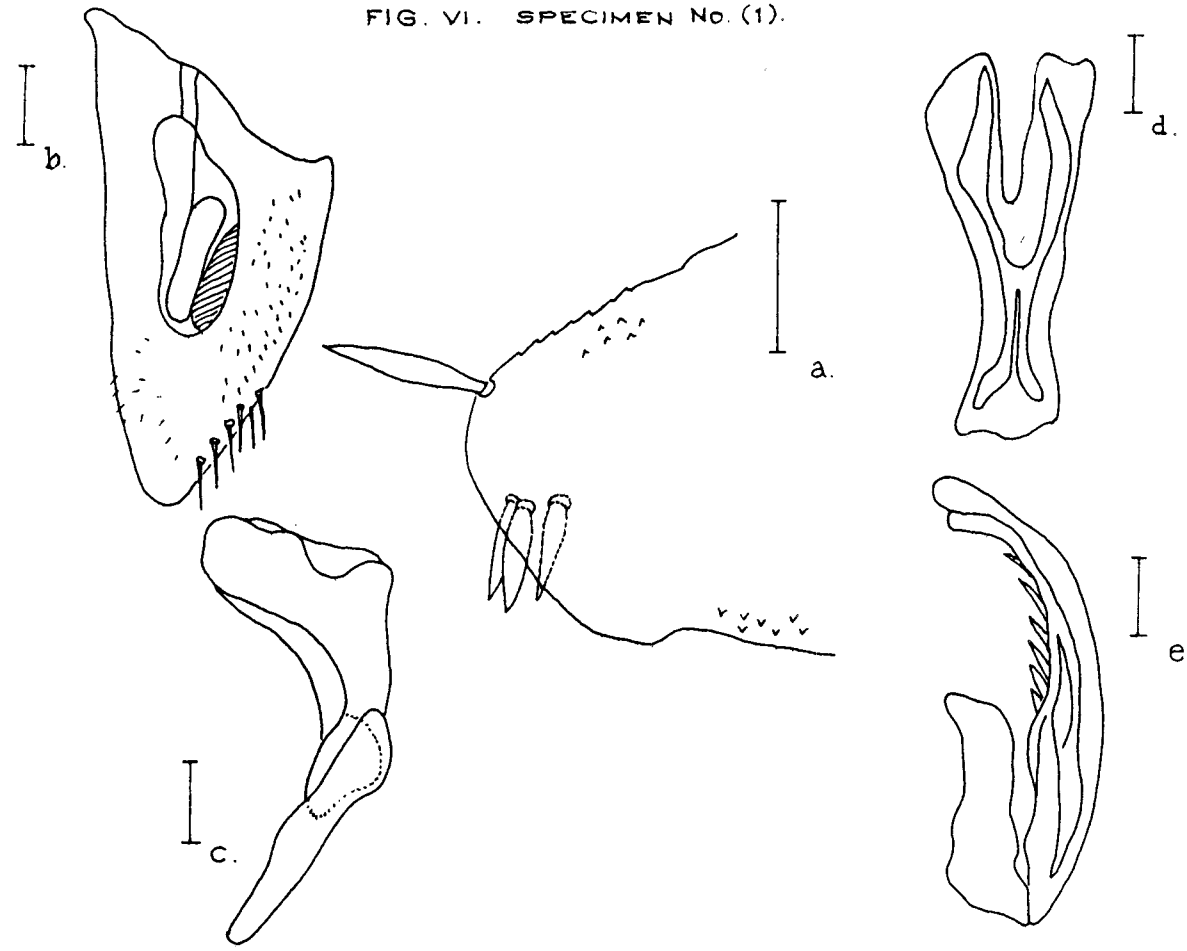
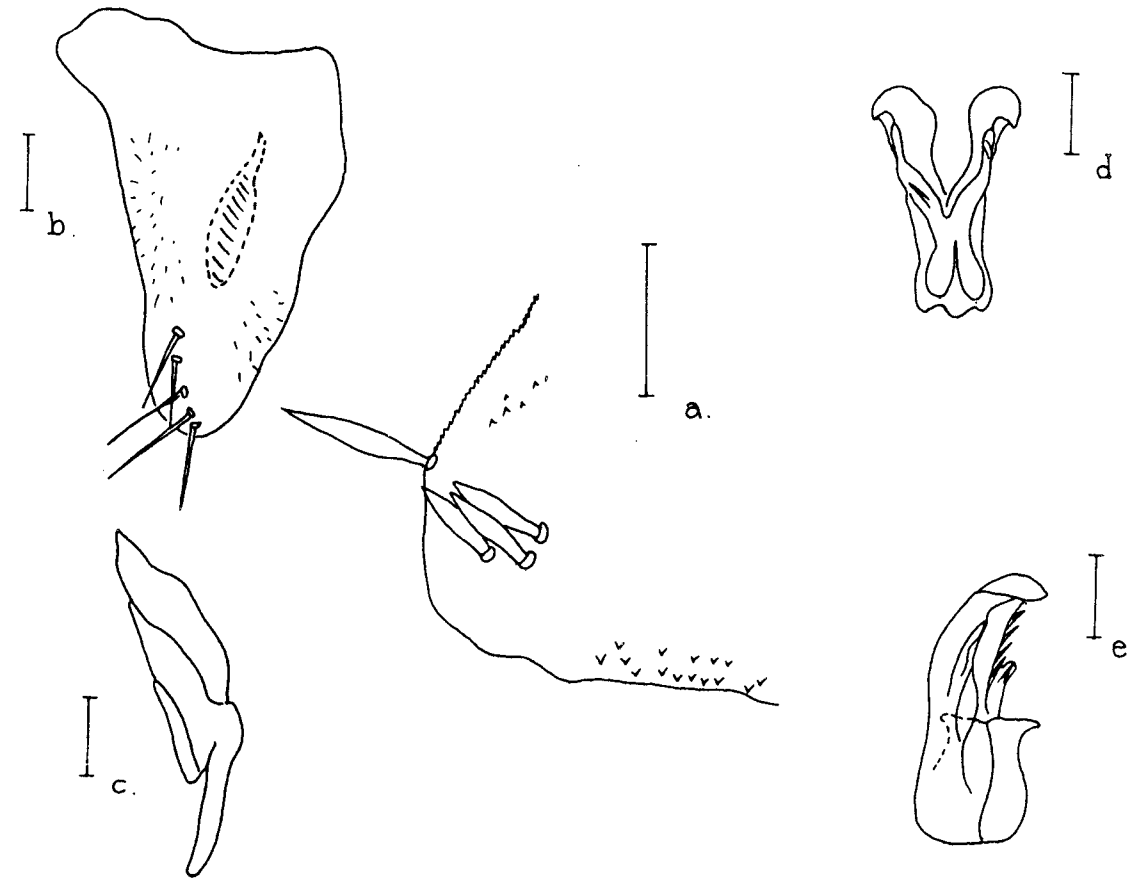


FIG. VII. SPECIMEN No. (2).



carinae with five pairs of spines distinctly separated.

Materials examined: One specimen from Mannuthy.

Specimen No.3 & 4 (Females)

Colouration: Vertex with broken anterior lines, pronotum without anterior black bands, basal and inner margin of clavus without black bands. Tegmen entirely green, compound eyes red in colour.

1.3. Recilia dorsalis (Motschulsky)

Colouration:

Male: Vertex and pronotum yellow to whitish, scutellum whitish, tegmen with a longitudinal zigzag stripe.

Female: Similar to male in colouration.

Male genitalia (Fig. VIII)

Pygofer: Longer than broad with numerous microsetae present in the outer margin towards apex.

Subgenital plates: Subtriangular with numerous setae on the outer margin.

Basal plate: Fused with aedeagus.

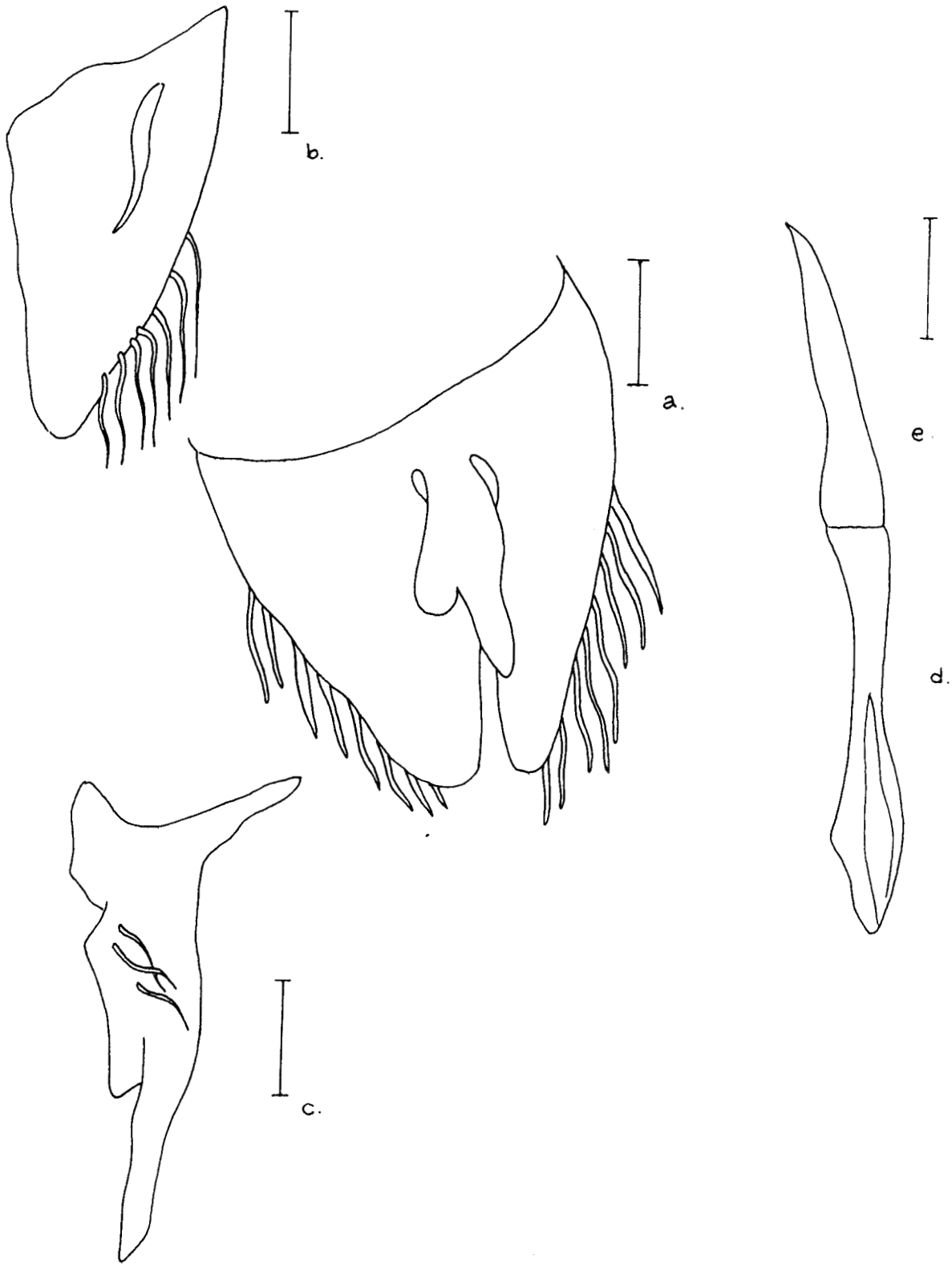
Paramere: Base terminated in to two processes, preapical lobe present, apical extension shorter than base, apex slightly convex, three setae near the lobe.

Aedeagus: Dagger shaped with a constriction in the middle, curved at tip, apex pointed.

Materials examined: Several specimens from Mannuthy, Kole, Pattambi and Pattikkad.

Fig. VIII.
Male genitalia of *Recilia dorsalis* (Mots.)

FIG. VIII . *Recilia dorsalis* (Mots)



1.4. Tettigella spectra (Distant)

Colouration:

Male: Vertex with four black spots, one quadrangular dark spot in between ocelli at base of vertex, there is a median apical black spot and two spots one each near the margins of vertex and frons. Five dark striae at the apex of vertex. Tegmen pale white or clear white, hindwing hyaline.

Female: Similar to male in colouration.

Male genitalia (Fig. IX)

Pygofer: Disto-dorsal corner round, disto-ventral corner curved, ten setae distributed on the dorsal side of pygofer.

Subgenital plates: Elongate, wider at base, tapering towards apex, nine setae present marginally.

Basal plate: Short medium, sclerotisation present at the base, arms diverging apart.

Paramere: Short, wider and angular at middle, curved and pointed at apex.

Aedeagus: Shaft slightly constricted at middle in ventral view.

Materials examined: Several specimens from Pattambi and Kole.

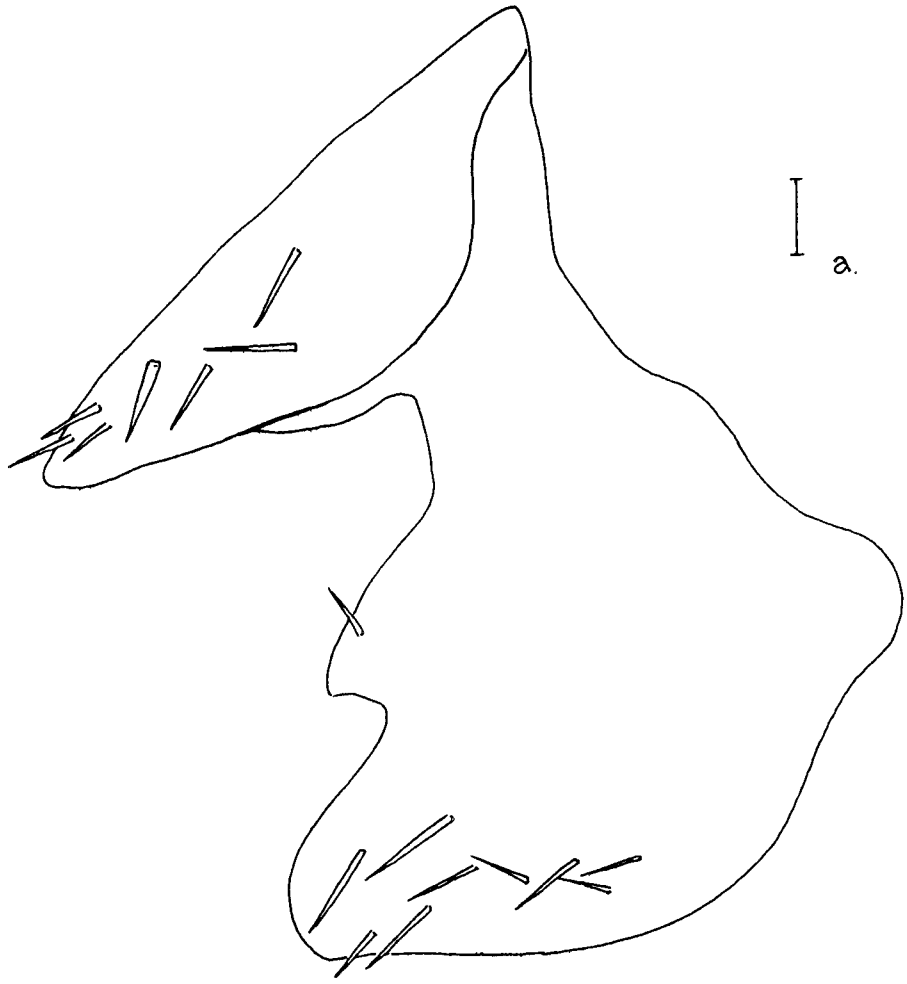
1.5. Exitianus indicus (Dist.)

Only few female specimens could be procured during the study. These specimens were identified by comparing with the specimens in the insect collections of the College of

Fig. IX.

Male genitalia of *Tettigella spectra* (Dist.)

FIG. IX. *Tettigella spectra*. (Dist.)



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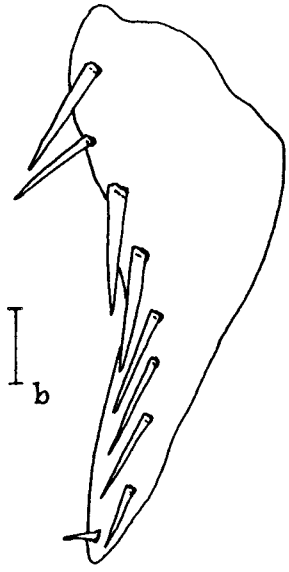

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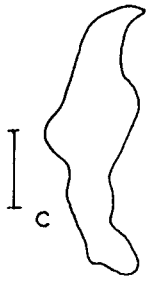

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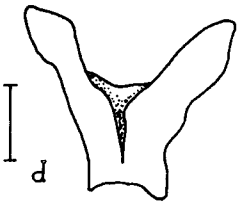

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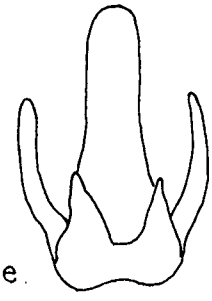


e

Horticulture and also with the descriptions given by Distant (1908).

Colouration.

Female: Vertex subangularly rounded in front, ochraceous, a transverse black fascia between eyes, pronotum and scutellum ochraceous; tegmina greyish, subhyaline, suffused with pale dull ochraceous veins.

2. Family Delphacidae:

Insects belonging to three genera viz., Nilaparvata, Sogatella and Matutinus were collected from paddy. They have been identified with the help of the key given by Mamman (1971).

2.1. Nilaparvata lugens (Stal)

Colouration.

Male: Vertex, pronotum, mesonotum, antennae and legs brown. Tegmina subhyaline with a dull yellowish tint, transverse and apical veins fuscous, an elongate black macula at clavel apex. Colour variation of the tegmens was noticed in some specimens.

Female: Similar to male in colouration.

Male genitalia (Fig.X)

Pygofer: Longer than broad, posterior opening little longer than broad, diaphrgm without any armature.

Paramere: Short, narrow medially, twisted, apex crumbled, inner angle produced in to two elongate processes,

lower one reflected inwards, outer angle bulged round.

Aedeagus: Elongate, tubular, wider in middle, apex narrow, gonopore one third from tip laterally with a row of 2 teeth ventral to gonopore.

Anal segment: A pair of spine like processes at the apex with a long anal style.

Materials examined: Several examples from Kole and Manmuthy

2.2. Sogatella furcifera (Horvath)

Colouration.

Male: Disc of vertex, pro and mesonota creamy yellow, lateral field of mesonotum, entero-lateral area of pronotum behind eyes, frons and genae dark brown, body ventrally brownish black, tegmina subhyaline, a deep brown macula at claval apex, apical half fuscous in anal area with venation deep brown.

Female: Similar to male in colouration.

Male genitalia (Fig. XI)

Pygofer: Moderately long, a medio-ventral button like projection, diaphrgm narrow, dorsally a highly sclerotised horse shoe shaped armature, tips of which projects out as a finger.

Paramere: Short, flattened, broad, basal half swollen at one side, distally furcate.

Aedeagus: Moderately long tubular, sinuate, broad at base narrow at apex, gonopore lateral to tip, two rows of

teeth, one on the left side, other on the ventral border.
Anal segment: Collar like, two long spinuous process, anal style short oblong.
Materials examined: Several specimens from Kole, Mannuthy and Pattikkad.

2.3. Matutinus pusanus (Dist.)

Colouration

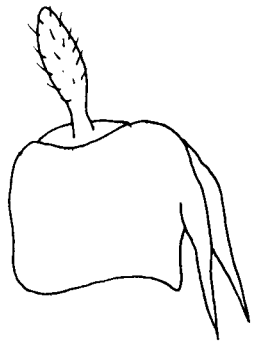
Male: Vertex, pro and mesonotal discs yellow, lateral field of pro and mesonata brownish fuscous; frons and genae deep brown, body beneath deep brown; tegmina subhyaline, an upper claval streak becoming macular at claval apex, a transverse linear discal spot beyond middle, a sub apical marginal suffusion continued along veins to apical margin leaving hyaline marginal spots in the cells.
Female: Similar to male in colouration.

Male genitalia (Fig. XII)

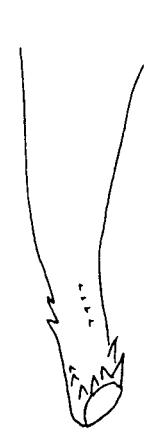
Pygofer: Longer than broad, diaphrgm produced into a dorso-median conical projection with two longitudinal thickenings forming a sub-triangular area having numerous minute teeth.

Paramere: Short, broad at base, medially narrow, broadened towards apex, with the outer angle produced into a narrow prolongation.

FIG. XII. *Matutinus pusanus* (Dist.).



f.



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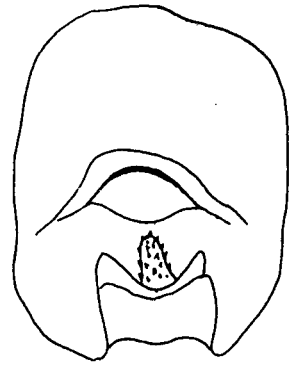

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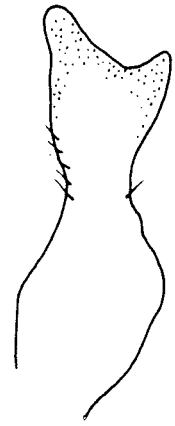


c.

FIG. X. *Nilaparvata lugens* (stal).

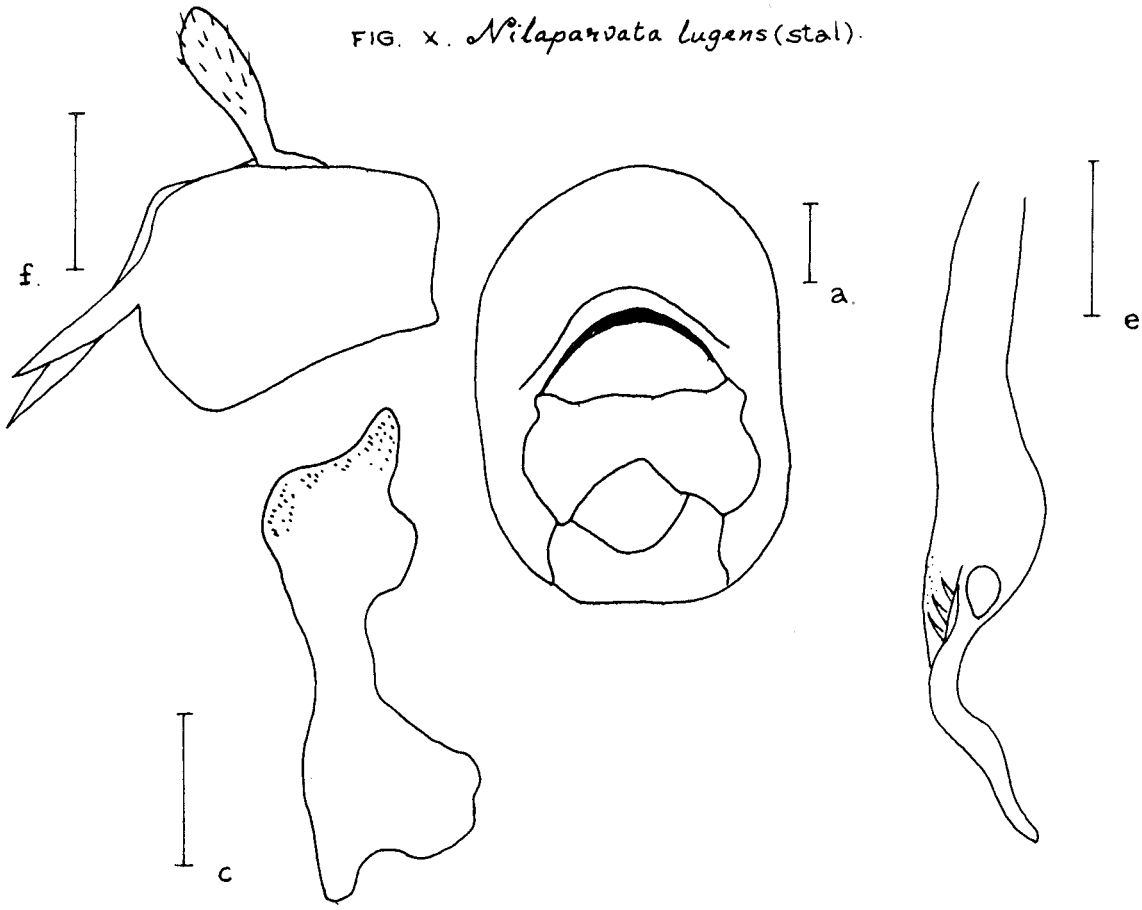


FIG. XI. *Sogatella furcifera* (Horv.).

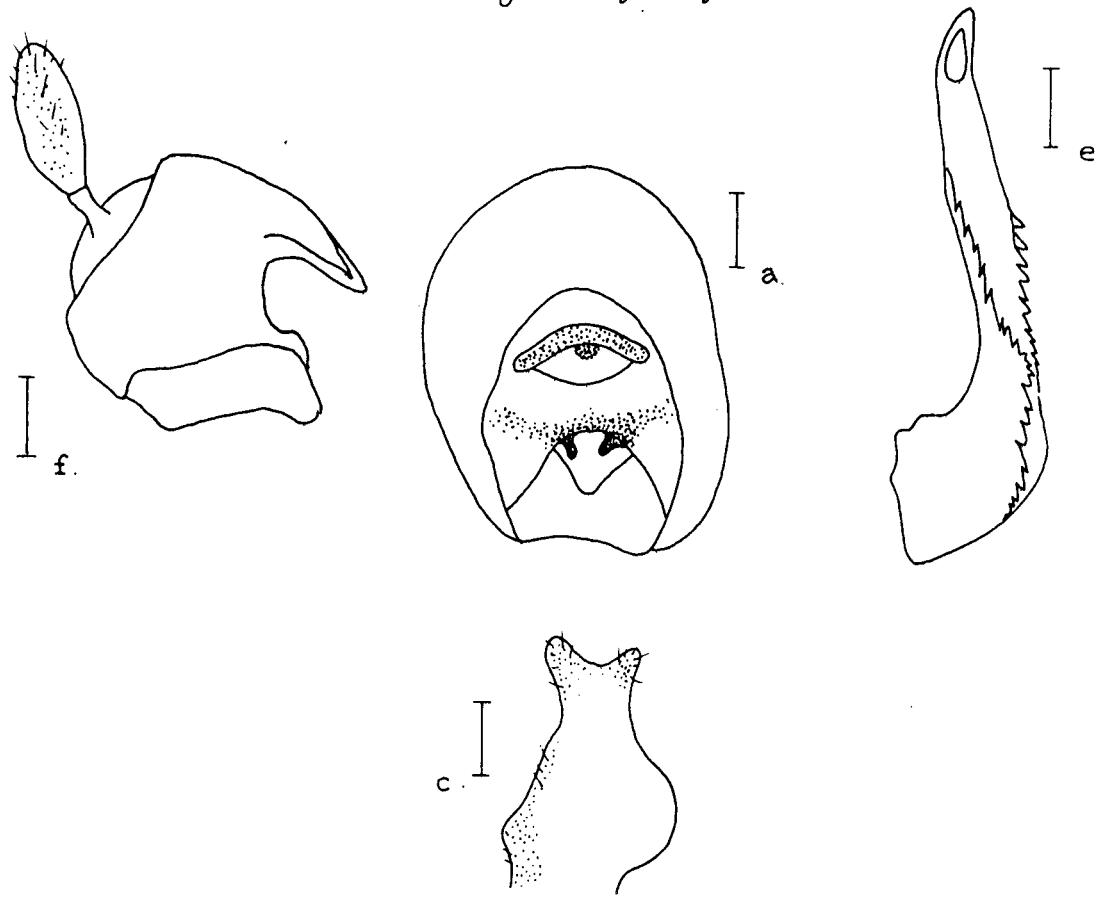


Fig. X.

Male genitalia of *Nilaparvata lugens* (Stal)

Fig. XI.

Male genitalia of *Sogatella furcifera* (Horv.)

Aedeagus: Long tubular, broader at base, narrowed apically, gonopore at tip with a row of spines all around, a row of 4 to 5 teeth laterally and two teeth ventrally about one third from apex.

Anal segment: Short, apical margin transverse, latero-apical angles produced ventrally into a pair of moderately long spinous process, short oblong anal style.

Materials examined: Few specimens from Kole and Mannuthy.

Family: Membracidae. Only females of the genus Nisia could be procured. These specimens were identified by comparing with the specimens in the insect collections of the College of Horticulture and also with the description given by Distant (1908).

3.1. Nisia nervosa (Motsch.)

Colouration

Female: Vertex with carinae picious and very finely granulose, space between them concave, wings creamy white, venation darker, first and second apical veins bifurcating, other veins simple.

Morphometric studies

Ratios on eye diameter (d) to interocular distance (io) and vertical distance next to eye (l) to length of vertex (L) of six species under Cicadellidae and Delphacidae viz., Nephotettix virescence (Dist.), N. nigropictus (Stal),

Recilia dorsalis (Motsch.), Tettigella spectra (Dist.) Sogatella furcifera (Horvath) and Nilaparvata lugens (Stal) are presented in the table I and II.

Table I. Eye diameter: Interocular distance of different species of Jassids and Delphacids.

Insect species	Male	Female
N. virescens (Dist.)	1:2.909±0.4215	1:3.518±0.0127
N. nigropictus (Stal)	1:3.434±0.4988	1:4.310±0.5392
R. dorsalis (Motsch.)	1:3.277±0.1127	1:2.628±0.1445
T. spectra (Dist.)	1:4.321±0.3470	1:5.070±0.4351
S. furcifera (Horv.)	1:1.324±0.1670	1:1.576±0.5203
N. lugens (Stal)	1:2.104±0.4017	1:1.899±0.1766

Table II. Vertical distance next to eye: Median length of vertex of different species of Jassids and Delphacids.

Insect species	Male	Female
N. virescens (Dist.)	1:1.285±0.0834	1:1.233±0.0407
N. nigropictus (Stal)	1:1.122±0.0564	1:1.230±0.1926
R. dorsalis (Motsch.)	1:1.075±0.0250	1:1.182±0.0922
T. spectra (Dist.)	1:1.333±0.2394	1:1.553±0.1659
S. furcifera (Horv.)	1.1.091±0.0756	1:1.174±0.6670
N. lugens (Stal)	1:1.040±0.0559	1:1.162±0.0637

Seasonal abundance of leaf and plant hoppers of paddy

While collecting leaf and plant hoppers, weekly population counts were observed for each locality at different growth stages of the crop. Weekly counts at different localities for different species are presented in Fig. XIII to XVI and in table III.

Discussion

DISCUSSION

The objective of the present investigation was to study the leaf and plant hoppers associated with paddy in the two important rice growing tracts of the state viz., Palghat and Trichur districts. Variation in the distribution of insect species in accordance with the geographical areas, climatological conditions and the varieties of crop plants were reported by different workers. There are morphological differences even between different populations of the same species as reported by Claridge (1981) in Nilaparvata lugens (Stal). Specific identification of insect pest populations has been found to go a long way in economic pest control.

Pawar (1975) reviewed the insect pests of rice all over the world in which he has included seven species of cicadellidae, seven species of delphacidae and one species of membracidae as insect pests of rice. But the author could procure only nine species of hoppers associated with paddy from different tracts of the state. They include Nephotettix virescens (Distant), N. nigropictus (Stal), Recilia dorsalis (Mots.), Tettigella spectra (Dist.), Exitianus indicus (Dist.), Nilaparvata lugens (Stal), Sogatella furcifera (Horv.), Matutinus musanus (Dist.) and Nisia nervosa (Motsch). Among these all but M. musanus have been reported as pests of rice in India and other East

Asian countries, while N. nervosa and N. indicus have not been recorded from Kerala by earlier workers.

Family: Cicadellidae

Ghauri (1971) published the differentiating characters of various species of Nephotettix. The two species collected by the author have been described and illustrated by him. However, the author could procure certain specimens showing variations from the above which probably does not amount to specific distinctions.

In N. nigropictus one male and one female specimens were found to be possessing red compound eyes. These specimens were otherwise similar to N. nigropictus. This may be considered as mutants of N. nigropictus. Hoshida (1970) also reported a red eyed specimen of Nilaparvata lugens from Japan.

The specimen numbered (1) is found to be exhibiting intermediate characters between N. virescens and N. nigropictus. In this, vertex is having marginal and sub-marginal black bands, pronotum with fine black band, apical third of tegmen black. These characters resemble with that of N. nigropictus but inner margin of clavus is not black, discal spot does not touch claval suture. These characters resemble with that of N. virescens as described by Ghauri (1971).

Male genitalia: Disto-ventral corner of pygofer with a small

lobe, disto-dorsal corner round, apex of aedeagus swollen. These characters resembles with N. nigropictus. Smaller spines on pygofer are three in number while in both N. virescens and N. nigropictus they are four in number. Six pairs of spines are found in aedeagal shaft while there are eight pairs in N. nigropictus and five pairs in N. virescens.

Because of these intermediate characters this specimen may be a natural hybrid in between N. virescens and N. nigropictus. Hybrids between these two species were reported by Ling (1968) and Usha Ramakrishnan et al. (1979). The characters of the hybrids described by them however were slightly different from those of this specimen. Ling reported that hybrids were not identical with either parent in respect of the submarginal black band on the vertex of the adults or number of spines on the aedeagus. Usha Ramakrishnan described the intermediate specimen as the marginal black bands absent in male, claval inner marginal black band absent, discal spot present in males but not touching the claval suture, apical third of tegmen is black in males, there is no striking difference between the genitalia of parents and intermediate specimens, but the number of spines on the pygofers varied from two to seven while it is usually four in N. virescens and N. nigropictus. Also the number of spines on the aedeagal shaft is variable. Most of these descriptions were found to be agreeing with specimen No.(1).

The specimen numbered (2) resembles N. cincticeps (Uhler) in colouration but genitalia almost resembles N. virescens. Vertex with marginal and submarginal black bands, anterior margin of pronotum with a pale black band, basal and inner margin of clavus colourless but tegmen is green coloured with no discal spot.

Apical part of aedeagus as wide as the immediately preceeding part, five pairs of spines on aedeagal shaft, internal process of paramere straight. These characters resemble with that of N. virescens. Further N. cincticeps has not been found distributed in India according to Ghauri (1971). Hence this may be a natural hybrid. Specimens numbered (3) and (4) also show variations in characters. Vertex is with broken anterior lines, pronotum without anterior black bands, basal and inner margin of clavus without black bands and tegmen entirely green. These also may be natural hybrids.

Viraktamath (1983) has also given a key to identify economically important species of cicadellidae which included Recilia dorsalis (Motsch.) and Tettigella spectra (Dist.). The specimens collected agrees with the descriptions given by the above worker. In R. dorsalis it was found that the basal plate is fused with the aedeagus while in T. spectra it was separated as in Nephotettix spp.

Only a female specimen of Exitianus indicus was obtained. Hence a detailed study of the genitalia was not possible but a description on the external morphology and colouration is given.

Family: Delphacidae

Hamman (1971) studied in detail the genitalia of Delphacidae and has given illustrations of the genitalia of different species. In the present study the author could procure three species of delphacidae viz., Nilaparvata lugens (Stal), Sogatella furcifera (Horv.) and Matutinus muscus (Dist.). Genitalic characters of all these three species agree well with his work. As reported by him colour variations in N. lugens was noticed by the present author also.

Family: Meenoplidae

Few specimens of Nisia nervosa (Motsch.) were obtained. Detailed genitalic study was not possible for want of male specimens. The specimen collected by the author agrees well with the descriptions given by Distant (1908).

Morphometric studies

Specimens when preserved either as dry or in liquids like formalin will loose their colour and become difficult to identify on the basis of colour. Genitalic studies even though highly reliable, is very cumbursome. New (1977) stated that head measurements are sometimes used for specific

separations in psocoptera. Kulshreatha et al. (1964) made morphometric analysis of Liothrips bosei Moulton (Phalaeothripidae) using length/width ratios of head and third antennal segment, relative length of postoculars and eyes, anteroangulars and anteromarginals,, and epimerals and post-angulars. Hence an attempt was made to find out whether the ratios between the eye diameter (d) to intecocular distance (ic) or/and length next to eye (l) to median length of vertex (L) could be utilised to separate out different species under these families. These ratios were used to compare between closely resembling spp. viz., Nephotettix virescens and N. nigropictus; Nilaparvata lugens and Sogatella furcifera. Ratios for Recilia dorsalis and Tettigella spectra were also worked out. Ratios for males and females were found out separately.

It was found that male specimens of N. virescens and N. nigropictus may not be separated out based on the ratio of eye diameter to inter-ocular distance since there is no difference between these two but there is difference for the ratio of length next to eye to median length. Vertex of N. virescens is more pointed. Hence this may be utilised for separating out these two species.

In case of female specimens there is difference for the ratio of eye diameter to interocular distance, but no difference for length next to eye to median length.

Between Sogatella furcifera and Nilaparvata lugens the only ratio which showed difference is the eye diameter to interocular distance of male specimens.

Ratios given in table I and II can be utilised for further studies and can be compared with other closely resembling species.

Seasonal abundance of leaf and plant hoppers of paddy

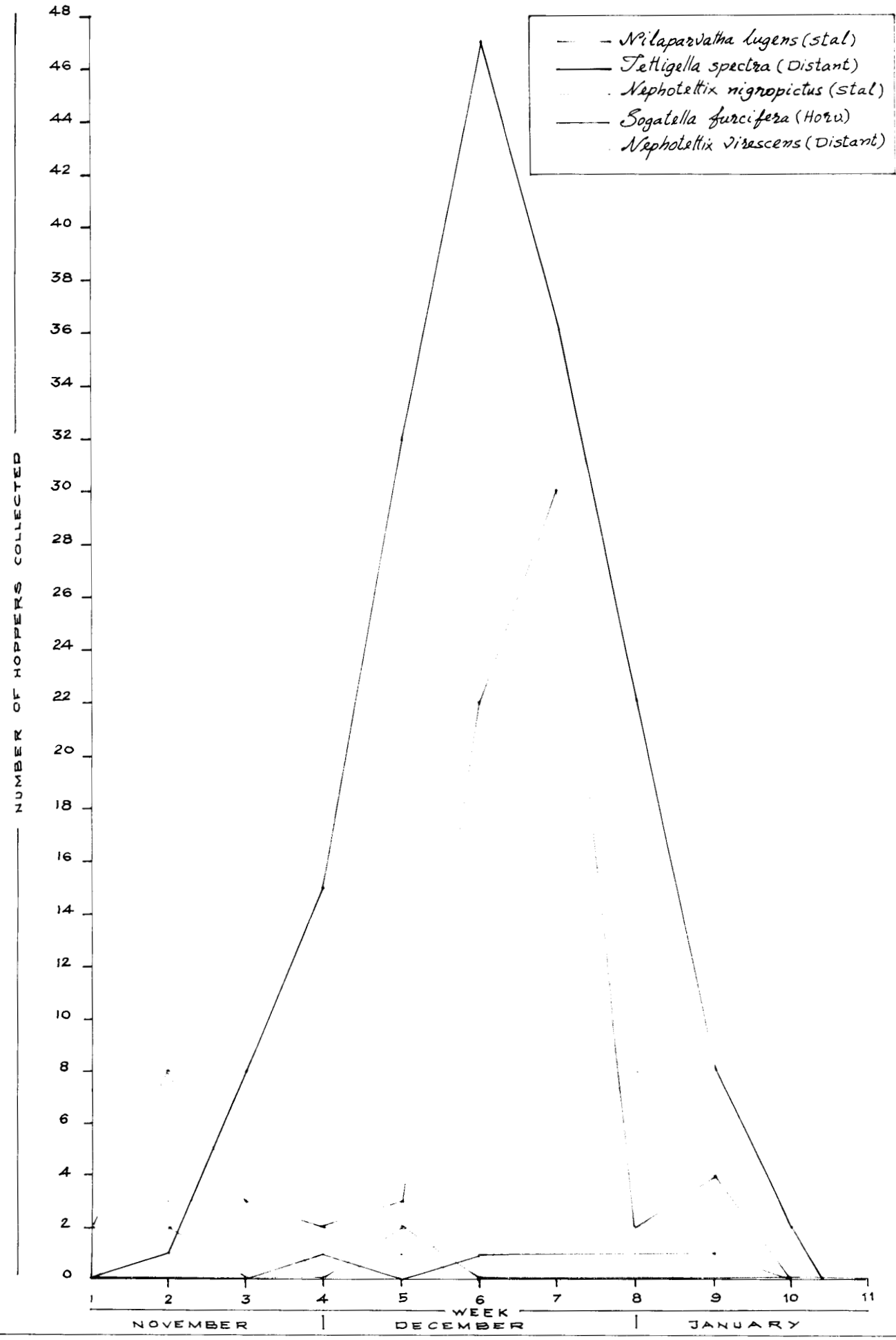
Even though counts were taken for only one cropping season for the present study, this gives an idea about the dominant species in the area and the population trend during the entire period of crop growth.

Pattambi (Fig. XIII)

The following observations were made at Pattambi showing the population trend of different leaf and plant hoppers on paddy. Among the different species of leaf and plant hoppers collected Tettigella spectra was the most abundant species followed by Nephotettix nigropictus and N. virescens. Populations of Nilaparvata lugens and Sogatella furcifera were very low and that of Recilia dorsalis was negligible.

Peak population of T. spectra coincided with panicle initiation stage. Two peak populations were observed in N. nigropictus, a small peak at tillering stage and a sudden build up one week after panicle initiation stage of the crop.

FIG. XIII. POPULATION FLUCTUATIONS OF LEAF AND PLANT HOPPERS AT PATTAMBI.



Trichur Kole (Fig. XIV)

The most abundant species was N. lugens followed by N. nigropictus and S. furcifera. Even though population of N. lugens was low during the earlier stages of crop growth, there was a sudden increase in population during the panicle initiation stage. Population of S. furcifera showed a gradual increase during tillering stage then gradually decreased after which a sudden build up was noticed during the panicle initiation stage.

Peak period of N. nigropictus was observed during tillering stage. The population of N. virescens was also maximum at the tillering stage but without any increase in the later stage of crop growth. The population of T. spectra was comparatively low.

Kannuthy (Fig. XV)

N. nigropictus was the most abundant species followed by N. virescens. Peak population of N. nigropictus was two weeks after panicle initiation stage. Populations of other species were comparatively very low.

Pattikkad (Fig. XVI)

Leaf and plant hopper populations were very low at Pattikkad during the cropping season. N. nigropictus and N. virescens were the predominant species in the area.

FIG. XIV. POPULATION FLUCTUATIONS OF LEAF AND PLANT HOPPERS AT KOLE (TRICHUR).

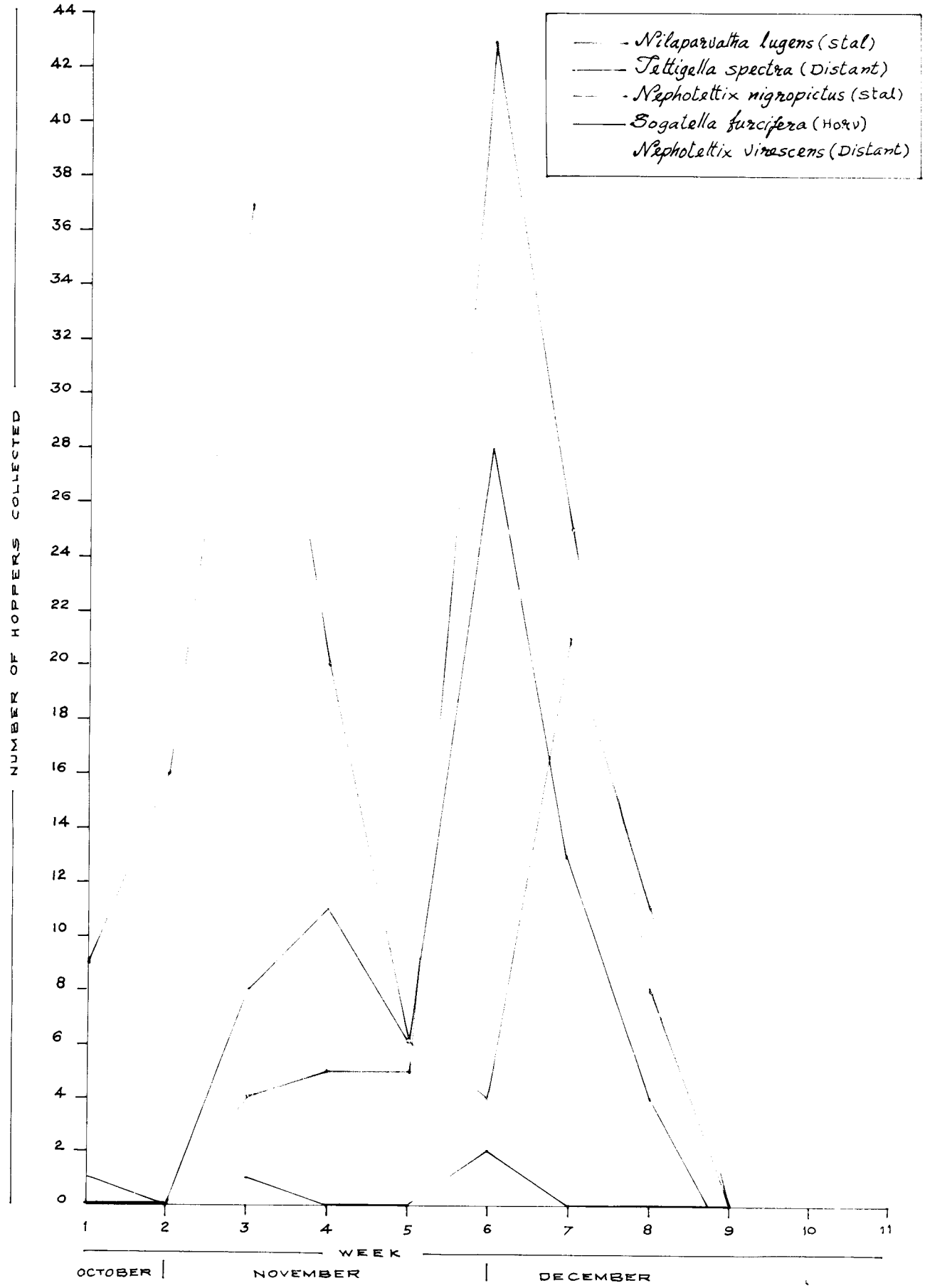
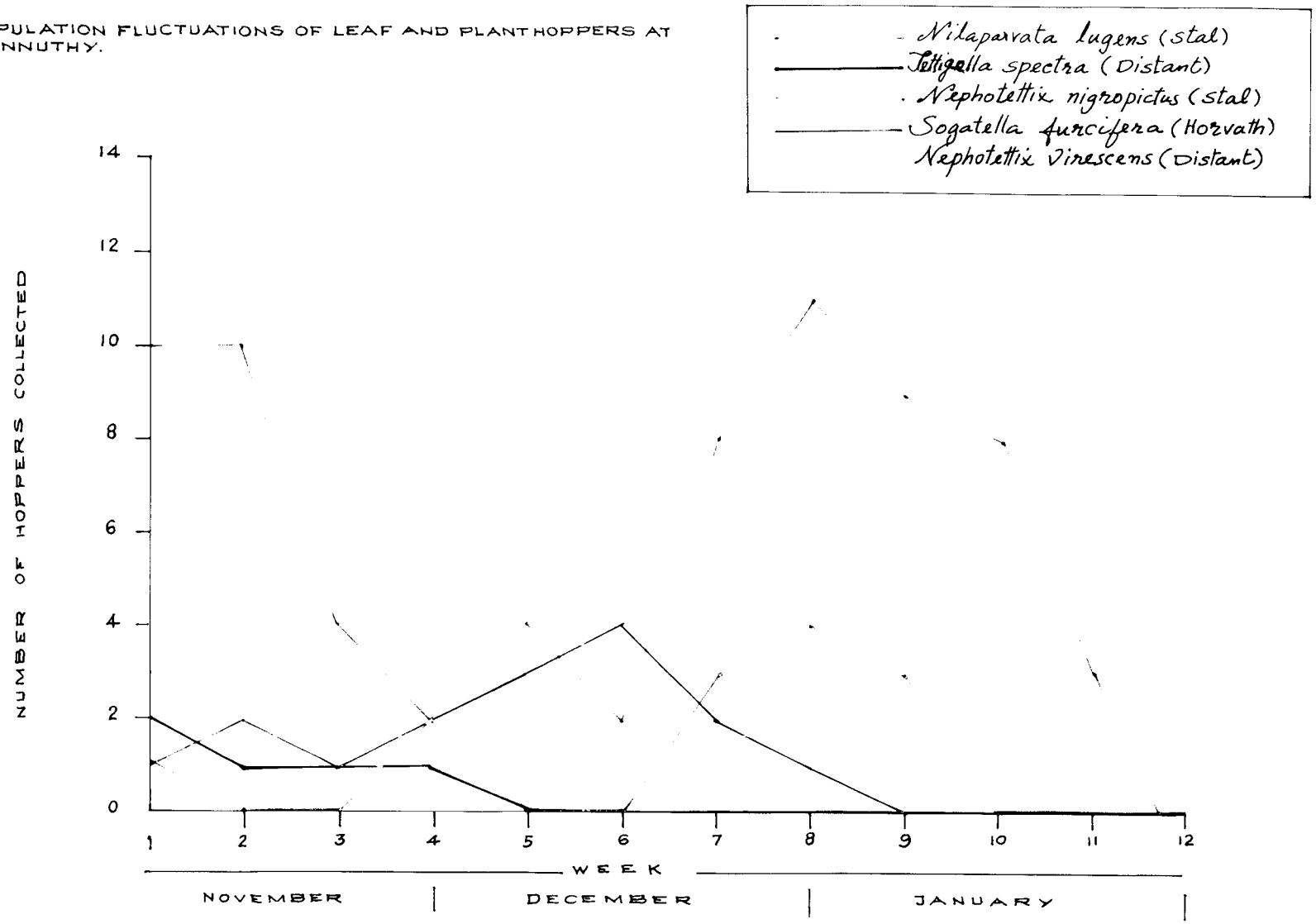


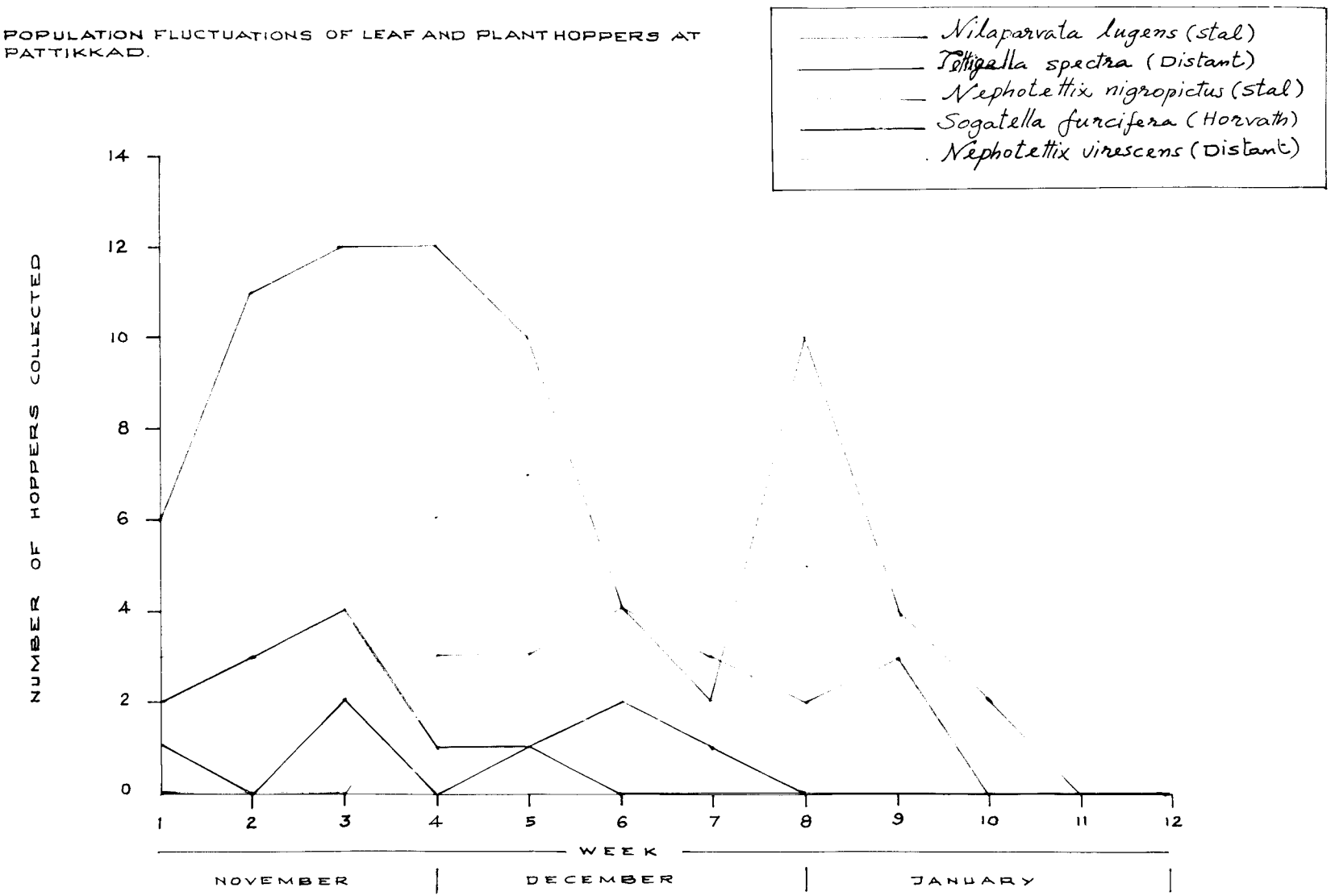
FIG. XV. POPULATION FLUCTUATIONS OF LEAF AND PLANT HOPPERS AT MANNUTHY.



Increase in the population of both the species were observed during the panicle initiation stage and then gradually declined, later there was another peak during earhead emergence.

Populations of N. lugens and S. furcifera were comparatively low and that of T. spectra was negligible.

FIG. XVI. POPULATION FLUCTUATIONS OF LEAF AND PLANT HOPPERS AT PATTIKKAD.



Summary

SUMMARY

Taxonomic studies were conducted on the leaf and plant hoppers associated with paddy in Kerala with a view to find out the correct identity of the species.

Leaf and plant hoppers were collected in every week from selected paddy fields of Kole, Pattikkad, and Mannuthy in Trichur and Pattambi of Palghat districts with a fixed number of sweeps from transplanting upto harvest. Collections from each field for each week were separately preserved in homeopathic vials with collection data. Later insects in all vials were sorted out, number of specimens collected in each week were noted, sexes separated, and each species were preserved in separate homeopathic vials. Vials were serially numbered and collection data were noted under each serially numbered species. General form and colouration of both sexes as well as genitalic studies of the male were conducted.

Author could collect nine species of leaf and plant hoppers viz., Nephotettix virescens (Dist.), N. nigropictus (Stal), Recilia dorsalis (Mots.); and Exitianus indicus (Dist.) belonging to the family Cicadellidae; Nilaparvata lugens (Stal), Sogatella furcifera (Horv.), and Matutinus pusanus (Dist.) coming under Delphacidae and Nisia nervosa (Motsch.) under

Meenoplidae. Descriptions of the above species are presented with illustrations of male genitalia except for S. indicus and N. nervosa for which male genitalic studies were not possible for want of male specimens. Among these species all but N. pusanus were reported to be occurring on paddy in India and other East Asian countries, while S. indicus and N. nervosa were not observed by earlier workers from Kerala. Two male and two female specimens of Nephotettix showing variations in characters from N. virescens and N. nigropictus were observed. These may be natural hybrids between N. virescens and N. nigropictus.

An attempt was made to find out whether closely resembling species can be separated based on head measurement viz., eye diameter to interocular distance and/or vertical distance next to eye to median length of vertex. It was found that there is difference between male specimens of N. virescens and N. nigropictus with regards to the ratio of vertical distance next to eye to median length of vertex, and in females of these species there is difference between the ratios of eye diameter to interocular distance. Similarly there is difference between male specimens of N. lucens and S. furcifera with regards to the ratio of eye diameter to interocular distance.

Seasonal abundance of leaf and plant hoppers were also studied taking counts from different fields. It was found that there is variation between different regions with regard to dominant species.

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Original not seen

TAXONOMIC STUDIES OF LEAF AND PLANT HOPPERS ASSOCIATED WITH PADDY IN KERALA

BY

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ABSTRACT

Taxonomic study on the leaf and plant hoppers of paddy was conducted to find out the various species of leaf and plant hoppers associated with paddy in Kerala.

Paddy fields from two important paddy growing tracts of Kerala viz., Trichur and Palghat were selected and weekly collections of hoppers were made. Collections were made with a fine mesh hand net for the entire cropping season from transplanting upto harvest. Fixed numbers of sweeps were taken from the same field in order to get an idea about the population fluctuations. Collections from each field for each week were separately preserved in homeopathic vials with collection data. Later insects in all vials were sorted out, number of specimens collected in each week were noted, sexes separated, and each species were preserved in separate vials. Vials were serially numbered and collection data were noted under each serially numbered species. Genitalia of males as well as general form and colouration of all species were studied. However genitalic studies of Exitianus indicus (Dist.) and Nisia nervosa (Motsch.) could not be conducted for want of male specimens.

Altogether nine species were collected viz., Nephotettix virescens (Dist.), N. nigropictus (Stal), Recilia dorsalis (Motsch.) and Exitianus indicus (Dist.) coming under Cicadellidae, Nilaparvata lugens (Stal), Sogatella furcifera (Horv.),

Matutinus pusanus (Dist.) belonging to Delphacidae and Nisia nervosa (Leth) under Meenoplidae. Among these species all but N. pusanus were reported to be occurring on paddy in India and other East Asian countries, while E. indicus and N. nervosa were not observed by earlier workers from Kerala.

Apart from these, two male and two female specimens of Nephotettix showing variations in characters from N. nigropictus and N. virescens were also obtained. These may be natural hybrids between N. virescens and N. nigropictus.

Certain morphometric studies were conducted using head measurements viz., eye diameter to interocular distance and/or vertical distance next to eye to median length of vertex. It was found that there is difference between male specimens of N. virescens and N. nigropictus with regards to the ratio of vertical distance next to eye to median length of vertex; and in females of these species there is difference between the ratios of eye diameter to interocular distance. Similarly there is difference between male specimens of N. lugens and S. furcifera with regards to the ratio of eye diameter to interocular distance.

Studies on the seasonal abundance of leaf and plant hoppers revealed that there is variation in the predominant species present in each area.