BIOLOGY AND POPULATION BUILD UP OF THE RICE WHITEBACKED PLANTHOPPER, *Sogatella furcifera* (Horvath) ON DIFFERENT RICE VARIETIES

BY

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THESIS

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Dedicated to my parents

DECLARATION

I hereby declare that this thesis entitled "Biology and population build up of the rice white-backed planthopper, Sogatella furcifera (Horvath) on different rice varieties" 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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CERTIFICATE

Certified that this thesis entitled "Biology and population build up of the rice whitebacked plant-hopper, Sogatella furcifera (Horvath) on different rice varieties" is a record of research work done independently by Sri.Ajith, P.P. under my guidance and supervision and that it has not previously formed the basis for award of any degree, fellowship or associateship to him.

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C O N T E N T S

LIST OF TABLES

(contd.)

LIST OF TABLES (contd.)

LIST OF ILLUSTRATIONS

LIST OF PLATES

INTRODUCTION

INTRODUCTION

The whitebacked planthopper, *Sogatella furcifera* (Horvath) (Delphacidae: Homoptera) was known as a pest of rice in Japan as early as 697 BC (Suenaga and Nakatsuka, 1958). The insect is distributed throughout South and Southeast Asia, China, South Pacific Islands and Northern Australia. It has also been collected from non rice areas like Mongolia, Siberia and South Kuril Islands (Mochida *et al.*, 1982).

Under favourable conditions, the insect breeds fast and assumes the status of a major pest of rice. The nymphs and adults suck the phloem sap resulting in reduced vigour, yellowing of leaves and delayed tillering and poor grain formation. Severely attacked seedlings show yellowing, wilting and eventual death (Khan and Saxena, 1984). The ovipositional punctures on leaves and leaf sheaths caused by gravid females predispose the rice plants to bacterial and fungal infections also. Further, the honey dew secreted by the insects causesthe development of sootymould on the leaves which affect the photosynthetic efficiency of the plants adversely.

The insect has assumed importance as a pest of rice recently, particularly in areas where cultivars resistant to *N. lugens* are grown successfully (Heinrich and Rapusas, 1983; Khan and Saxena, 1985). Generally, *N. lugens*

maintains a numerical superiority over S. furcifera, but on cultivars resistant to N. lugens, S. furcifera tends to multiply faster. It is believed that the ecological niche vacated by N. lugens is gradually being occupied by S. furcifera (Khan and Saxena, 1984). This has been particularly true in areas where there is continuous cropping of high yielding varieties using high doses of nitrogenous fertilizers.

In Kerala, subsequent to the introduction of high yielding rice varieties, N. lugens became a serious pest of the crop. Rice production in the Kuttanadu and Kole areas was severely affected during 1973 and 1974, owing to outbreaks of the insect (Nalinakumari and Mammen, 1975). As a viable strategy to counter the damage by N. lugens, many rice cultivars resistant to the insect, bred in the Rice Research Stations of Pattambi and Moncombu, were released and are being cultivated on a large scale. The possibilities of S. furcifera replacing N. lugens in such areas and the pest becoming a serious problem to rice cultivation in the state cannot be ruled out. In this context it will be desirable to identify varieties resistant to both the insects. Efforts in this line have already been initiated in other research centres in India. But no work has been done on this aspect in Kerala so far.

Hence investigations were taken up covering the relative resistance of high yielding rice cultivars commonly cultivated

in Kerala to S. furcifera, the mechanisms of resistance, biology and population build up of the insect on the test cultivars, interspecific competition between the pest and N. lugens and the alternate hosts of the insect.

REVIEW OF LITERATURE

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2.1. General

The whitebacked planthopper, Sogatella furcifera (Horvath) (Homoptera: Delphacidae), was known as a pest of rice in Japan as early as 697 B.C. (Suenaga and Nakatsuka, 1958). It was first described by Horvath as Delphax furcifera in 1899. The genus was changed to Sogatella by R.G. Fennah of the Common wealth Institute of Entomology in 1963.

The Delphacidae includes more than 1100 species. Twenty nine species were determined to belong to the genus Sogatella including Sogatella furcifera which has two sub species distinct (Distant) from India and pallescens (Distant) from India and Srilanka (Fennah, 1963). Nasu (1967) rewieved the literature on the taxonomy and morphology of S. furcifera.

S. furcifera is widely distributed throughout south and Southeast Asia, China, South Pacific Islands and Northern Australia and it has also been collected from non-ricegrowing areas such as Mongolia, Siberia and the South Kuril Islands during summer and autumn seasons (Mochida et al.,1982).

The appearance of S. furcifera as a pest of rice has been reported in many rice growing countries of Asia such as Cambodia (Caresche, 1933), Malaya-Peninsula (Miller

and Pagden, 1930; Corbett, 1934), Vietnam (Britton et al., 1962; Tao and Ngoan., 1970), Japan (Nasu, 1965), Indonesia (Oka and Mochida, 1976; Mochida et al., 1978), Pakistan (Mahar et al., 1978; Inayatullah et al., 1987), China (Xu, 1982) and Nepal (Gyawalli, 1983).

In India, Fletcher (1916) reported the occurance of the pest in Bengal and Bihar causing serious loss to the rice crop. Serious damage by the pest was reported from West Bengal (Banerjee, 1956; Choudhary, 1965; Chatterjee, 1971; Mishra, 1977, Chatterjee et al., 1979), Madhya Pradesh (Mishra, 1916; Gangrade, 1960), Punjab (Atwal et al., 1967; Sidhu, 1979), Surat, Poosa and Nagpur (Lefroy, 1903-04), Himachal Pradesh (Bhalla and Pawar, 1975), Orissa (Sathyapathy et al., 1977) and Andhra Pradesh (Reddy et.al., 1978; Vaidya and Kalode, 1981). As reported by Dhaliwal and Jeswant Singh (1983), S. furcifera was first recorded in Punjab in 1966 and outbreaks of the pest occurred in 1972, 1975, 1978 and 1981. Heavy infestation of the pest was reported from Uttar Pradesh by Verma et al., (1979) and from Haryana by Kushwaha and Singh (1986).

Gubbaiah et al.,(1987) recorded the incidence of S. furcifera in Mandya, Karnataka during the Kharif season of 1986 and this was reported to be the first record of the insect in Karnataka.

2.2. Biology and Ecology

2.2.1. Incubation period:

At natural temperature the incubation period of *S. furcifera* eggs varied in different places in India. It was reported to be six days in Cuttack (Mishra and Israel, 1968), 3 to 5 days in Punjab (Atwal *et al.*, 1967) and 6 to 7 days in Andhra Pradesh (Vaidya and Kalode, 1981).

The incubation period varied from 8 to 15 days in China (Liu *et al.*, 1982) and from 5.2 to 10.5 days in Vietnam (Tao and Ngoan, 1970). Incubation periods of varying durations were reported by different workers in Japan such as 5.8 days (Murata, 1927), 8.3 days (Esaki and Hashomoto, 1937), 8.9 to 14.0 days (Tokunaga and Kidera, 1948) and 5.4 to 8.6 days (Harukawa, 1951).

2.2.2. Nymphal duration:

The nymphal duration of *S. furcifera* varied from 8.4 to 13.1 days in Punjab (Atwal *et al.*, 1967) and 12 to 17 days in Andhra Pradesh (Vaidya and Kalode, 1981). Vaidya and Kalode (1981) also gave the duration of five instars as 2 to 3, 2 to 3, 3 to 4, 3 to 4 and 2 to 3 days respectively.

The nymphal duration was reported to be 16.3 to 42.9 days (Murata, 1927), 13.6 to 25.8 days (Esaki and Hashimoto, 1937) 12.4 to 13.5 days (Tokunaga and Kidera, 1948), 11.5 to 20.0 days

(Harukawa, 1951) 9.6 to 15.4 days (Tao and Ngoan 1970), 11.5 days (Pablo, 1977) and 11.5 days (Liu et al., 1982).

2. 2.3. Adult Longevity

According to Atwal et.al. (1967) the longevity of macropterous female adults varied from 1 to 9 days. In Japan when the macropterous females were reared on the seedlings of susceptible rice varieties grown in test tubes at room temperature, the longevity of the insect recorded were 18.8 to 34.5 days (Murata, 1927), 23.8 to 31.6 days (Esaki and Hashimoto, 1937) 10.3 to 11.8 days (Tokunaga and Kidera, 1948), 7.0 to 41.1 days (Harukawa, 1951) and 2.3 to 16.0 days (Tao and Ngoan, 1970). Pablo (1977) reported the adult duration to be a minimum of 6 days and a maximum of 65 days with an average of 28.6 days.

In Japan the longevity of macropterous male was reported to be 18.6 to 31.8 days (Murata, 1927), 18.0 to 25.9 days (Esaki and Hashimoto, 1937) and 9.3 to 23.1 days (Harukawa, 1951). In Vietnam Tao and Ngoan (1970) reported the duration of macropterous adult duration as 1.9 to 10.7 days. In 1977, Pablo observed that the longevity ranged between 3 to 31 days with the mean being 17.8 days.

Atwal et al. (1967) reported the duration of brachypterous female in the range of 5 to 11 days with a mean of 7.1 days.

2.2.4. Pre-ovipositional period

Varying pre-ovipositional periods of macropterous females of S. furcifera has been reported in Japan by different workers viz., 3.1 to 5.1 days (Murata, 1927), 5 to 13 days (Esaki and Hashimoto, 1937), 4.9 to 6.7 days (Tokunaga and Kidera, 1948) and 2 to 8 days (Harukawa, 1951).

Pablo (1977) reported the pre-ovipositional period to be 2.7 days in Philippines, when the insect was reared at 27.29°C on 25 days old TN-1 potted seedlings. In China the period was reported to be 3.9 days by Liu et al. (1982).

The mean pre-ovipositional period of the brachypterous and macropterous female was reported as 3 to 7 days and 3 to 9 days respectively in China (Liu et al., 1982). According to Vaidya and Kalode (1981) the pre-ovipositional period was found to be 3 days in Punjab.

2.2.5. Fecundity

Huang et al., (1984) reported that 110.6 to 295.6 eggs per female were laid with more eggs being laid during the day than at night. Eggs were laid mostly on leaf sheaths at the base of the rice plant, though some eggs were laid on leaf blades also. According to him oviposition was more on young plants at the tillering stage especially when there was a

high density of plants and at temperatures between 20 and 30°C.

According to Vaidya and Kalode (1981) the ovipositional period extended up to 12 days with maximum oviposition between the seventh and tenth day . Feccundity ranged between 300 to 350 eggs per female as reported by Suenaga (1963). Liu et al. (1982) reported that the macropterous females in the first three generations laid an average of 117.7, 70.1 and 36.7 eggs respectively, whereas according to Vaidya and Kalode (1981) the average was 164 eggs per female. The hibernation was observed only in the egg stage of the life cycle as reported by Miyake (1966).

2.2.6. Population peaks and number of generations

In North Japan S. furcifera completed 1 to 3 generations per year, while 5 to 6 generations per year were reported from Southeast Japan. The adults from the overwintering generations generally emerged from late April to May, while those of the fifth generation emerged from the middle of October to the middle of November (Suenaga, 1956).

Tao and Ngoan (1970) reported that in South Vietnam S. furcifera completed 16 generations per year and that a higher degree of infestation of the pest was noticed during the wet season as compared to the dry hot season.

Miyake (1966) observed three population peaks in Hiroshima Prefecture, ie., from late June to early July, from middle August to late August and from late August to mid September. Bae et al. (1968) reported that in Korea the insects had four population peaks in an year ie., in early June, late July, August and in September.

According to Johraku et.al. (1974), in Japan, the abundance of S. furcifera was influenced by the extent of migration. Other factors influencing the population build up in Japan were warm spring water in paddy fields (Kawada, 1954) and cool air in mountain in winter (Suenaga, 1966).

In the annual report of CRRI, Cuttack (Anon, 1974) it was reported that the WBPH appeared in the rice crop from September onwards. Its population increased gradually and reached a peak in the middle of November and then abruptly declined and became negligible in the beginning of December.

The insects remained active all round the year and the population fluctuated depending upon the type of rice cultivation practiced in the region, availability of alternate hosts, presence of natural enemies and existence of favourable environmental conditions (Hinckley, 1963; Alam, 1967).

2.2.7. Weather condition

According to Miller and Pagden (1930) pest attack was noticed after a slight rainfall and high humidity was an important factor favouring outbreak of the pest in Japan.

Similarly low rainfall and absence of typhoons during summer were also reported to cause high infestation of the pest. (Murata and Hirano, 1932; Yashiro, 1939).

Mochida (1964) reported that the increased sunshine in April-June in Japan led to severe attack of the pest. Dyck et al.,(1977) observed that high temperature and low rainfall in the tropics and high temperature and low rainfall with ample irrigation in the temperate areas resulted in severe attack of the pest. Garg and Sethi (1980) reported that weekly averages of 28.59°C of temperature, 69.55 per cent of relative humidity, 8.18 hours of sunshine and 0 to 71.7 mm of rain were favourable for the S. furcifera outbreak in Delhi.

During the period of its appearance in CRRI, Cuttack, the maximum and minimum temperatures ranged from 25.6 to 30.6°C and 14.8 to 22.6°C respectively, the relative humidity from 48 to 94 per cent sunshine hours from 0 to 10.5 hours and rainfall from 0 to 33.1 mm/day (Anon, 1974).

Lever (1946) and O'Connor (1952) reported heavy attack of the pest after a spell of dry weather. Mochida (1964) observed that high infestation of the pest occurred when there were dry spells in the cropping system.

2.2.8. Natural enemies

According to field observation by Miyashita and Ito (1961) the nymphs of plant and leaf hoppers were controlled

by a group of spiders. The mirid, Cyrtorhinus lividipennis, the spiders, Thirids, Erygonids and Lycosids and nematodes were the main natural enemies and their density in the field was positively correlated with that of the delphacids (Luo, 1985).

2.3. Damage

The symptoms produced on the rice plants attacked by S. furcifera varied according to the population density, duration of feeding, rice cultivars involved and growth stages of crop (Mochida et al., 1982). The initial symptom on rice plants due to the infestations by S. furcifera was yellowing and as the infestation progressed hopper burn symptom appeared on the plants. Infestations appeared in the later stages of plant growth and the hopper burn appeared in patches in the field ranging in size from a few m^2 to about 25 m^2 and finally extended to large areas. The small seedlings were killed due to heavy oviposition injuries and sucking of sap by adult (Maki, 1917; Okamoto, 1924; O'Connor, 1952; Suenaga and Nakatsuka, 1958; Hinckley, 1963; Atwal et al., 1967; Oka and Mochida, 1976; Mochida et al., 1978).

S. furcifera caused direct damage to the crop by feeding, leading to hopper burn and by ovipositional injury (Hinckly, 1963). Infested crop failed to produce fully filled grains because of retardation in development in cooler

areas of Japan (Kuwayama, 1954). According to Mahar et al. (1978) the nymphs as well as the adults of S. furcifera attacked the flag leaves and panicles of most of the plants in the field. Similar observations were made by Khatri and Gangrade (1982). According to them panicle length, grain weight and number of grains per panicle were also decreased due to the attack. They also reported that the growth stages of the plants most susceptible to damage by S. furcifera were the tillering and booting stages.

Noda (1986) reported that in Japan S. furcifera damaged the ears of rice plants during 1982 and 1983 and many feeding marks were observed on the glumes by scanning electron microscopy indicating that the insect inserted the stylets into the tissues which resulted in the discolouration of the glumes. He also noted that the feeding activity of the progeny of immigrants of S. furcifera was the greatest during late July to mid August which is the heading period of rice in Japan.

But according to Iitomi et.al. (1985) no yield loss was resulted from the presence of upto 35 nymphs of S. furcifera per hill during the growth stages from the panicle formation to full ripeness. Saini (1984) stated that the population build up of S. furcifera resulted in 10 to 40 per cent yield loss of grains in Punjab, India, causing damage to about 1000 hectares. Vaidya and Kalode (1981) reported that the younger seedlings (15 to 30 day old) were more favourable to population build up

of the insect than older ones. According to Khatri and Gangrade (1981) the plants were more susceptible to the attack of S. furcifera at the tillering stage than at the booting and heading stages.

2.4. Varietal Resistance

Gunathilagaraj et.al. (1983) reported four methods for evaluating varietal resistance in rice varieties against S. furcifera namely, seedling bulk test, nymphal survival test, population development test and feeding rate test. Saxena and Khan (1984) suggested the free choice and no choice tests and seedling bulk test for evaluating resistance to S. furcifera.

In Vietnam, Tao and Ngoan (1970) reported that IR-5 and IR-8 were more susceptible to S. furcifera than the local varieties . Hynh (1975) reported that the variety TN-37-2 (IR 1561-228-3) resistant to N. lugens released in 1973 was susceptible to S. furcifera. Choi et al. (1973) reported that the varieties Colombo, Muthumanickam and Pankhari 203 were resistant and Mudgo, Co-22 and Vellailangayan were moderately susceptible to S. furcifera. Gunathilagaraj and Chelliah (1984) evaluated 222 rice accessions from 7 countries for resistance to S. furcifera by using the seedling screening technique and found a damage rating of three on 0-9 scale in 86 accessions and the accessions ARC 10550, ARC 6650, T7, IET 5741,

IET 6315, IET 6123 and IET 6311 were found to be highly resistant. Veluswamy et al. (1986) evaluated rice varieties IR 5 to IR 64 for resistance to Nephotettix viresence, S. furcifera and Nilaparvata lugens and found IR 62 and IR 64 to be highly resistant to the three pests, while IR 5, IR 36, IR 46 and IR 60 were found moderately resistant. Pathak et.al. (1986) in a screening trial found eight varieties including IET 6288 and Ptb 33 as resistant to S. furcifera. In the field evaluation of rice accessions for resistance to whitebacked plant-hopper and leaf folder, Kushwaha and Singh (1986) found sever saccessions to be resistant to both the pests. In the screening trial conducted at Banswara Agricultural Research station, the rice cultures RP 1831 - 36-1-4, RP 1832-23-3-4, AR- 26-5-3-5 and Pusa 587-2-1 were found to be highly resistant to S. furcifera (Tripathi and Pandya, 1987).

According to Tokunaga and Kidera (1948) the upland variety Shenscho was more susceptible than the low land varieties 'Taishomochi' and 'Shin Asahi'. These varieties showed marked difference in the number of eggs laid by the insects and the growth rate of nymphs. High glucose content in plants imparted susceptibility on upland varieties, as reported by Suenaga (1950).

The screening technique for identifying infestation by S. furcifera was perfected in International Rice

Research Institute, Manila, Philippines (Anon, 1980).
A long list of varieties having multiple resistance to plant and leaf hoppers were published by Pablo *et al.* (1975). Out of 6715 varieties from the germplasm bank of IRRI, Pablo (1977) screened out 128 resistant varieties including N 22 and Ptb 33. Recently more than 36,000 rice varieties from the germplasm collection from the IRRI have been screened for resistance to the pest and 270 wer found to be resistant in IRRI (Saini *et al.*, 1982).

Hernandez and Khush (1981) studied the genetics of 14 resistant varieties and they found that in 12 varieties the resistance was governed by a single dominant gene while in the other two it was governed by a single recessive gene. Several species of wild rice like *Oryza rufipogon* from Srilanka and *O. sativa* var. *spontanea* from India were also identified as resistant (Anon, 1979).

Sai-Krishna and Seshu (1980) indicated that a single dominant gene governed resistance in the varieties Ptb 33, ARC 14636, ARC 14766 and that a single recessive gene governed resistance in ARC 6650 and ARC 14394. Veluswamy and Heinrich (1985) reported that the varieties IR 5, IR 36, IR 56, IR 60 and IR 62 adversely affected the population build up of *S. furcifera*.

Monogenic rice cultivars with genes Wbph 1, Wbph 2, Wbph 3, wbph 4 and Wbph 5 for resistance to S. furcifera and digenic cultivars with genes Wbph 1 + Wbph 2, Wbph 1 + Wbph 3, Wbph 1 + 1 unidentified recessive gene and Wbph 2 + 1 unidentified recessive gene were tested for their effect on S. furcifera growth and development (Rapusas and Heinrichs, 1985). Sixteen rice cultivars were monogenic type. In these monogenic cultivars, the level of resistance with the five different genes were similar except in the population growth test, in which Podiwi A 8 (wbph 4) was the least resistant. IR 2035 - 117 - (Wbph 1 + Wbph 2) was the most resistant cultivar. In this variety, high resistance level was indicated by low WBPH survival, long nymphal period, low growth index, low female weight, and low population growth. Other digenic cultivars like NP 130, C 15662 - 2 and ARC 5752 have the same major gene for resistance but were less resistant and for most of the growth parameters these were equal to monogenic cultivars.

Romena et al., (1986) screened 48554 acessions of rice from 76 countries for resistance to S. furcifera and identifie 401 accessions as resistant. Out of these, 351 accessions were from Nepal, India & Pakistan. She stated that in contrast to rice 47.2 per cent of the wild rice accessions

consisting of 28 species primarly from Oryza minuta and O. officianalis groups were found resistant. Khan and Saxena (1986) documented the literature on the strategy in germ plasm evaluation in various countries and listed the sources of resistance used in breeding varieties with multiple resistance to different plant and leaf hoppers. Pathak et al. (1986) in a screening trial found that eight varieties including IET 6288 and Ptb 33 showed resistance to S. furcifera.

2.5. Mechanism of resistance

2.5.1. Preference - non preference

Leeuwangh (1968) reported that S. furcifera were usually abundant during the early stages of the plant growth. Alam (1971) and Dyck et al. (1977) reported that in the field rice plant age has greater influence to reduce the pest density. According to Vaidya and Kalode, (1981) both the nymphs and adults exhibited similar preference for feeding and shelter on the preferred varieties and that the preferred varieties received more eggs than the resistant ones.

The orientational and ovipositional response of S. furcifera were identical for both susceptible and resistant cultivars as reported by Rodriguez – Rivera, (1972) and Pablo (1977). Miyake and Fujiwara (1961)

reported distinct ovipositional preference for the host plant in young stage and for high chlorophyll content rather than plants approaching maturity. The observation made by Auclair and Baldos (1982) was that the nymphs have a tendency to move away from resistant plants after 24 hours of caging. In 1985, Khan and Saxena studied the behavioural and physiological response of S. furcifera to selected resistant and susceptible rice cultivars. According to them, the orientation of S. furcifera after one hour was identical in both the cases but after 8 hours significantly more insects settled on the susceptible TN-1.

2.5.2. Antibiosis

Pathak (1971) reported that the insects reared on non-preferred varieties laid fewer eggs and developed smaller populations. Similar observation were given by Rodriguez-Rivera (1972) and Vaidya and Kalode (1981). Rodriguez-Rivera (1972) stated that the preference for feeding, shelter and oviposition are not always related. They also reported that the varieties ARC 5752 and C5 17 were resistant to S. furcifera during the seedling stage and were susceptible during the early panicle stage. The nymphal survival and life span and fecundity of adults were adversely affected by the resistant varieties though the hatching of eggs was not affected. IRRI report, (Anon, 1972)

also gave similar observations namely shorter life span of adults, fewer number of eggs laid by them and high mortality of nymphs on resistant plants than on the susceptible variety TN-1.

Vaidya and Kalode (1981) observed loss in vigour, prolonged nymphal period, smaller size of adults and reduced longevity and fecundity of females. In 1972 Rodriguez – Rivera also reported the adverse effect of resistant cultivars on the egg hatchability of S. furcifera. According to Vaidya and Kalode (1981) population build up of S. furcifera in the second generation was distinctly lower on resistant varieties as compared to the susceptible variety, TN-1. In 1982, Auclair and Baldos observed that more number of S. furcifera males emerged from resistant varieties. Heinrich and Rapusas (1983) reported that the population build up was considered as a criterion for assessing the level of resistance in rice cultivars to S. furcifera.

In 1985 Khan and Saxena studied the growth and development of S. furcifera on different rice varieties. According to them the quantity of food ingested and assimilated from resistant cultivars was lower as compared to TN-1 and the growth rate of the insect was higher on TN-1 plants. Adult survival and fecundity, egg hatchability and population increase were also lower on resistant

varieties. However the oviposition was not markedly different in resistant and susceptible varieties.

2.5.3. Feeding

Sogawa (1973), following the method of Naito (1964) used the number of salivary marks on the plant surface due to Stylet probing by the insect as a criterion for assessing the feeding behaviour. Sogawa and Pathak (1970) measured the feeding rate of S. furcifera by the honey-dew excretion test. The honey dew excretion by the plant and leaf hoppers was related to the resistance of the rice varieties to the insects (Pathak & Saxena 1980). It has also been demonstrated that the difference in honey dew excretion was due to difference in the food intake by the insects on resistant and susceptible varieties. Auclair and Baldos (1982) observed that the rate of honey dew excretion was 267 times less on the resistant varieties

Khan and Saxena (1984) reported an electronic device to record the feeding behaviour of S. furcifera on susceptible and resistant rice varieties. According to them insect probed readily and fed for longer duration on susceptible varieties whereas the insect made brief and repeated probes on resistant varieties.

Gunathilagaraj and Chelliah (1985) studied the feeding behaviour of S. furcifera on 30, 45 and 60 days old rice plants of seven resistant and one susceptible

rice varieties in the laboratory. The preference of the hoppers for different varieties was studied in terms of feeding marks made and the amount of honey dew excreted. The insect made more feeding marks and excreted less honey dew on resistant varieties as compared to the susceptible TN-1. The number of feeding marks increased with increased plant age, while honey dew excretion decreased.

2.6. Alternate Host

Earlier investigations in Japan showed that S. furcifera could thrive on Panicum crusgalli, Poa annua and Alopeculas aqualis and the emerged adults were mostly macropterous which migrated to paddy fields (Miyake and Fujiwara, 1962; Miyake, 1966; Kuno, 1968).

According to Vaidya and Kalode (1981) S. furcifera could survive and reproduce on Chloris barbata, while on Echinochloa colonum, Paspaldicum germinatum, Leersia hexandra and Panicum spp they could reach upto adult stage and these served as temporary food plants. Huang et al. (1985) reported that rice was the preferred host for the development of S. furcifera but the other hosts were Echinochloa crusgalli, Setaria viridis, Eluerina indica, Alopeculus aqualis, Arundiniella hirta, Leersia

japonica, *Echinochloa crusgalli* var. *mitis* and *Eregrostis ferrugena*. In addition they also reported that the insect could survive on barley and wheat.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. Raising rice plants for mass culturing of S. furcifera

The rice cultivar TN-1 which is highly susceptible to the whitebacked planthopper, S. furcifera was used for mass culturing the insect. The seedlings were raised in clay pots (35 x 35 cm). Wet land soil collected from paddy fields of the Instructional farm of College of Agriculture, Vellayani, was dried, homogenised and filled in the pots leaving two inches of space at the top. The seeds were soaked in water for one day and kept for germination in small gunny bags for another day. On the third day, the germinating seeds were sown in the pots as in a wet nursery. The pots were placed inside large insect proof cages. Water level of 3 cm was maintained in the pots from the seventh day after sowing of the seeds.

Clay pots of size 15 x 15 cm were used for transplanting the seedlings. The pots were filled with soil as done in the nursery pots. Fertilizers in the form of urea, super phosphate and muriate of potash to give 90:45:45 kg of NPK/ha were added to the soil in the pots (Anon, 1989) . Half nitrogen, full phosphorous and half potash were applied as basal dose and the remaining half nitrogen and half potash were applied at the active tillering stage. Twenty day old seedlings were transplanted

at the rate of 2-3 seedlings per pot. Water level in each pot was maintained at 2 cm throughout the growth period of the crop.

The plants in the pots were confined in cylindrical transparent cages made of 250 micron thick polyester film supplied by m/s Karnataka Sales Corporation, Bangalore, immediately after transplanting (Plate 1). The cages were 70 cm in height and 12 cm in diameter. The upper end of the cages were closed with close-meshed nylon nets, held in position with rubber bands. Two ventilation holes (5 x 10 cm) covered with voil cloth, were provided on the sides of each cage for air circulation. The ventilation holes were on opposite sides provided at a distance of 25 cm and 50 cm from the base respectively. The pots with the caged plants were placed in cement basins containing water to a height of 5 cm. This arrangement helped to maintain optimum humidity inside the cages.

Seedlings were raised in nursery pots at fortnightly intervals and transplanted to the mainpots so that a steady supply of plants of suitable age was available periodically to continue the mass culturing of the insect for various experiments.

3.2. Mass culturing of S. furcifera

Ten pairs each of the adults of S. furcifera collected from field were introduced in the caged TN-1

Plate - I Mass rearing of *S. furcifera* on potted TN-1 plants caged with Polyester film.

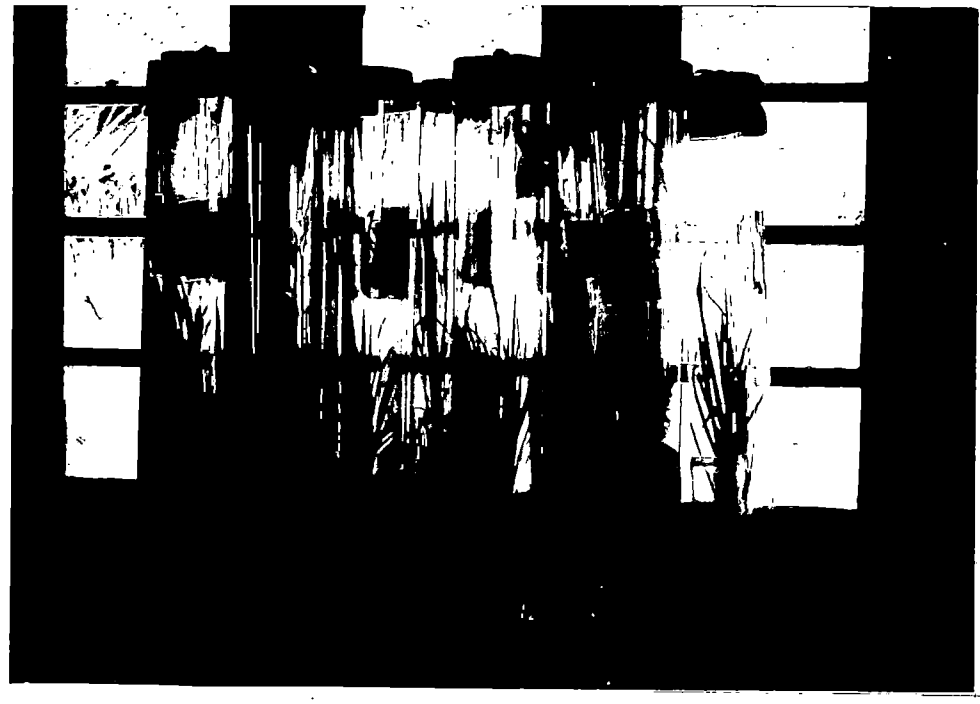


Plate I

plants, 15-20 days after transplanting, using an aspirator. The aspirator was made by closing one end of a glass tube (5 cm long and 4 mm in diameter) with muslin cloth and inserting that end to a plastic tube, 25 cm long and 6 mm in diameter. This arrangement helped to suck in the insects through the open end of the glass tube and to retain them at the closed end of the tube, so that they could easily be blown out to rice plants.

Three days after release, the gravid females were located and transferred to fresh caged plants for oviposition. This was done on every alternate day so that the nymphs emerged from the eggs laid on the plants of each pot would not vary significantly in age. Adequate number of plants with eggs were obtained at regular intervals so that the required number of test insects of different instars were available during the entire period of experimentation. The insects were retained on the same potted plant till the outer leaves showed yellowing due to feeding and/or oviposition Once the yellowing symptoms were observed, the plants were cut at the base with a sharp blade and the nymphs were transfered carefully to fresh caged plants of similar age. The water level in the pots and in the cement trays were maintained at constant levels throughout the period.

3.3. Preliminary screening

The preliminary screening trials conducted were seedbox screening test, orientation and settling response test and population build up test. The rice cultivars used for preliminary screening are listed in Table 1.

3.3.1. Seed box screening test

Seed boxes (60 x 45 x 10 cm) made of G.I. sheets were used. These were filled to a height of 7 cm with wet soil collected from the paddy fields. The pre-germinated seeds of all the cultivars were sown in each seed box in 15 cm long rows across the width with a spacing of 5 cm between rows. Each box thus had one row of each cultivar except TN-1 for which three rows were maintained (Plate 2). The seedbox screening test was conducted in complete randomised design and with three replications.

Eight days after sowing, the seedlings in the seed boxes were thinned to 20 per row. The water level was maintained constant at 2 cm from the seventh day after sowing the seeds. The seed boxes were kept inside large sized wire mesh cages with wooden frame to prevent the entry of parasites and predators. Twelve days after seeding, the seedlings were infested with second and third instar nymphs of *S. furcifera* at the rate of 5 to 6 nymphs per seedling from the stock culture. This was done by cutting the TN-1 paddy plants infested with second and third instar

Table 1. Rice cultivars used in the screening for resistance to S. furcifera

cultivars	parentage			source
TN-1	DGWG	x	Yuvan Chung	RRS, Moncompu
Ptb 33	Pure line selection from Arikrai			RARS, Pattambi
Cul 93	Jaya	x	Ptb 33	RRS, Moncompu
Triveni	Annapoorna	x	Ptb 15	RARS, Pattambi
Cul 126	Jaya	x	Ptb 33	RRS, Moncompu
Jyothi	Ptb 10	x	IR8	RARS, Pattambi
Pavizham	IR8	x	Karivennal	RRS, Moncompu
Karthika	Triveni	x	IR 1539	RRS, Moncompu

Plate -II Seed box screening test-before the rows are thinned.

Plate II

Plate II

nymphs of the insect, at the base using a sharp knife and gently tapping them over the seed boxes uniformly.

The test plants were observed daily for damage caused by S. furcifera. The damage rating was done on a row basis when ninety per cent of the test plants in the susceptible check row (TN-1) were killed. The plant damage was graded on a 0 to 9 scale as described below (Anon , 1980)

Grade	Criteria	Rating
0	no damage	highly resistant
1	very slight damage	resistant
3	first and second leaves with orange tips, slight stunting	moderately resistant
5	more than half of the leaves with yellow orange tips; pronounced stunting	moderately susceptible
7	more than half the plants dead; remaining plants severely stunted and wilted	susceptible
9	all plants dead	highly susceptible

Damage grade

Score	Rating
0 to 3	resistant
3.1 to 5	moderately resistant
5.1 to 7	susceptible
7.1 to 9	highly susceptible

3.3.2. Orientation and settling responses and damage rating in no-choice and free-choice tests

Orientation and settling response of the insect to the test cultivars were ascertained by free-choice test and seedling damage was recorded in free-choice and no-choice tests.

3.3.2.1. Free choice test

The GI trays used for seedbox screening test were used for free-choice test also. The pre-germinated seeds of the cultivars were sown in 40 cm long rows across the length of the trays with a spacing of 5 cm between rows. Eight days after sowing, each row was thinned to 20 seedlings per row. Twelve days after sowing, the seedlings were infested with second and third instar nymphs of *S. furcifera* from the stock culture at the rate of five to six insects per seedling using the same method adopted in the seedbox screening test. The trays were kept inside wire mesh wooden cages for protection from natural enemies. Water-level of 2 cm was maintained in the tray from the seventh day after seeding. The experiment was done in split plot design treating each row as plot, and with three replication for each treatment.

The nymphs settled on each seedling in each row were counted and recorded at intervals of one, eight, twenty - four and forty eight hours after infestation. After each

counting, the insects were disturbed and allowed to settle again.

The seedling damage was recorded when 90 per cent of TN-1 seedlings were killed, on a 0 to 9 scale (Anon, 1980).

3.3.2.2. No-choice test

The planting for the no-choice test was carried out as done in the free-choice test, except that each row was excluded from the others by using vertical wire mesh curtains (60 x 30 cm) and covering the top portion with cloth so that the insects could be confined to each cultivar without access to the other cultivars. The experiment was laid out in split plot design with three replications. The seedling damage was recorded when 90 per cent of TN-1 seedlings were killed on the 0-9 scales (Anon, 1980).

3.3.3. Population build up test

Seedlings of the eight test cultivars were raised separately in large clay pots (35 x 35 cm). Collection of soil, filling of pots, transplantation of seedlings, application of fertilizers and maintenance of water level were done as described in para 3.1. Sufficient number of pots with plants were maintained for each cultivar.

Three pairs each of freshly emerged S. furcifera adults were introduced on the caged plants. The surviving insects were transferred to fresh caged plants of similar age

as and when the outer leaves of the exposed plants showed yellowing due to oviposition/feeding. The counts of the surviving nymphs and adults were taken at intervals of 10, 20, 30, 40, 50 and 60 days after the introduction of the insects. The experiment was laidout in split plot design with four replications for each treatment (cultivar).

3.4. Assessment of the mechanisms of resistance

Based on the criteria described in para 3.3.1, Cul 126, Jyothi were selected as resistant and Karthika and Pavizham were identified as moderately resistant cultivars. The mechanism of resistance in these cultivars were studied in detail with TN-1 as the susceptible check.

3.4.1. Assessment of ovipositional preference

Twenty day old seedlings of the test cultivars were transplanted at the rate of two seedlings per pot (35 x 35 cm). Water level was maintained at 3 cm in the pots. The potted plants required for the experiment were raised and maintained as described in para 3.1. Ten days after transplanting, 20 gravid females each were released on the caged plants.

The insects were allowed to oviposit for three days. After three days the plants in each pot were cut at the base using a sharp knife and examined under a 20 x stage microscope. The oviposition marks were located in the leaf

sheath as well as in the midribs and the number of eggs were counted and recorded, by dissecting the plant tissues at the oviposition sites. The data were statistically analysed by treating the experiment as a 5 x 2 factorial one with four replication for each treatment.

3.4.2. Assessment of antibiosis

The antibiosis of the test cultivars was ascertained by studying nymphal duration, nymphal survival, adult longevity, fecundity, egg hatchability, sex ratio and feeding behaviour of the test insect. These experiments were conducted at three growth stages of the test cultivars viz. seedling, tillering and booting stages.

Plastic cups (7 x 7 cm) were used for raising plants for all the experiments conducted in the seedling stage of the test cultivars and for experiments in the tillering and booting stages plants raised in clay pots (15 x 15 cm) were used. Wet land soil collected from paddy fields, dried, and homogenized were used for filling the plastic cups and clay pots. The plastic cups and clay pots were filled with the soil leaving 2 cm and 5 cm at the top respectively.

For the experiments in the seedling stage pre-germinated seeds of the cultivars were sown in the plastic cups (Plate3).Seven days after sowing the excess seedling were thinned off leaving 2 to 3 seedlings per cup. For experiments in the tillering and booting stages, twenty day old seedlings

Plate - III Rice plants raised in plastic cups for studies in the seedling stage.

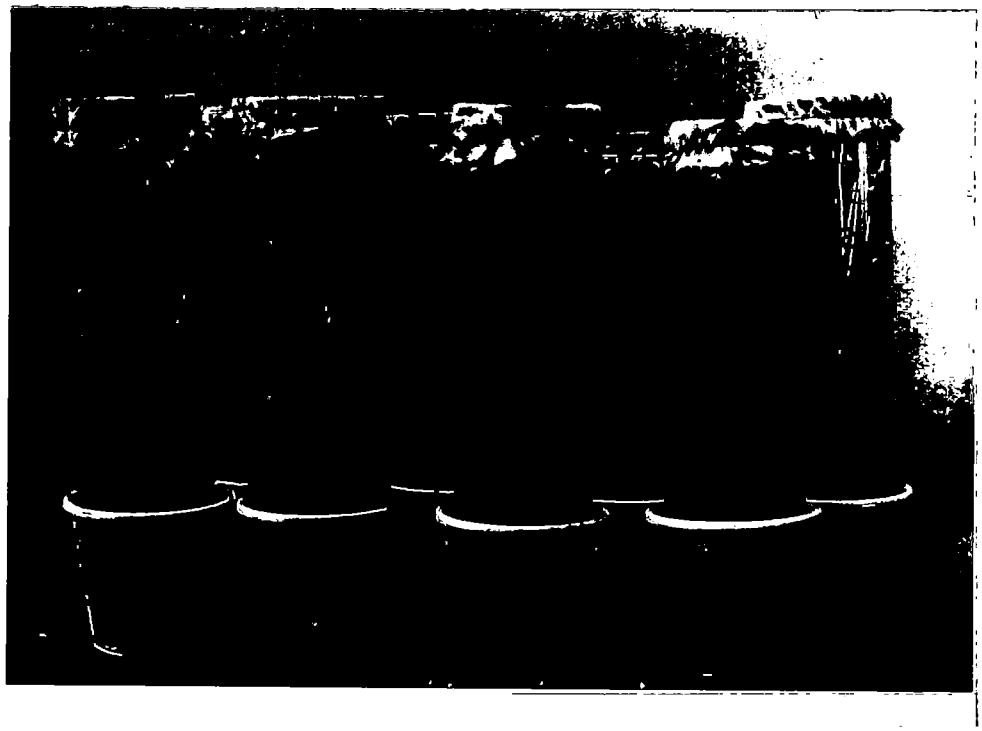


Plate III

were transplanted at the rate of 2 to 3 seedlings per pot. When yellowing of the outer leaves due to injuries caused by oviposition and feeding of the confined insects were noticed, the insects were transferred to fresh plants of identical age kept ready for the purpose. The water level was maintained at 1 cm in the plastic cups and 2 cm in the clay pots throughout the period of experiment. Atmost care was taken against the accidental introduction of parasites and predators in the caged plants in all the experiments.

The plants in the plastic cups and clay pots were confined in polyesterfilm cages as described in para 3.1.

3.4.2.1. Assessment of nymphal duration

Nymphal duration of S. furcifera when reared on the test rice cultivars during the seedling, tillering and booting stages were studied in three sets of experiments.

3.4.2.1.1. Seedling stage

When the seedlings in the plastic cups were 15 days old, one healthy seedling was retained in each cup and the rest were thinned. A circular polyester film disc (5 cm dia) was cut and a hole was made at the centre. The seeding was carefully passed through the hole and the disc was positioned just above the water level in the cup using four pegs. A circular black paper disc of similar size was placed over the

polyester film disc. This arrangement was to locate the moults correctly. One newly emerged first instar nymph of S. furcifera was released on each seedling and the seedling with the discs was placed in a polyester film cage. Moults fallen on the black paper were promptly removed after recording the duration of each instar in days. Observations were continued till the nymph became adult. The nymphal duration was thus ascertained in all the test cultivars. The experiment was carried out in completely randomised design and with six replications.

3.4.2.1.2. Tillering/booting stage

Forty five day old plants raised in clay pots were used for the experiment in the tillering stage. One main culm was retained and other plants were removed from each pot by cutting at the base using a sharp knife. The culm was passed through a hole made at the centre of a circular polyester film disc of 11 cm diameter and was placed above the water level using four pegs as supports. A black paper of 10 cm diameter was placed over the disc by making a hole at the centre and by passing the culm through it. One newly emerged nymph of S. furcifera was released on the culm using an aspirator and the culm was enclosed in a polyester film cage. Observations on the duration of each instar were recorded till the nymph became adult as described in para 3.4.2.1.1. The experiment was in completely randomised design and was replicated four times.

3.4.2.2. Assessment of nymphal survival

Nymphal survival of S. furcifera was ascertained in each of the test cultivar in seedling, tillering and booting stages in three sets of experiments. Fifteen day old seedlings raised in the plastic cups and 45 and 75 days old plants in the clay pots were enclosed in polyester film cages. Ten freshly emerged S. furcifera nymphs were introduced on the plants. The experiment was replicated four times and completely randamised design was adopted. The number of nymphs were recorded daily until they moulted as adults or dead and the percentage of nymphs moulting as adults were worked out from the data.

3.4.2.3. Assessment of adult longevity

A pair of freshly emerged adults were released on the plants of the test cultivars at seedling, tillering and booting stages of the crop in three sets of experiments. The adult duration was recorded in days for the male and female separately until all the insects in each replication died. The experiment was laidout in completely randomised design and with four replications.

3.4.2.4. Assessment of fecundity

The insects from the stock culture were reared on 30 days old plants of the test cultivars for one generation

before starting the experiment so as to eliminate the carry over effect of the susceptible check cultivaron which the stock culture was maintained. The method of rearing adopted was as described in para 3.1.

A pair of newly emerged adults were released on each rice cultivar at seedling, tillering and booting stages in three separate experiments. One day after release, the insects were transferred to fresh plants of identical age and the oviposited plants were cut at the base, the leafsheaths and leaf midribs were examined under a 20 x microscope and the eggs were counted after dissecting the tissues at the oviposition sites. The process was repeated daily until all the ovipositing insects died. The experiment was conducted in completely randomised design and with four replications.

3.4.2.5. Assessment of egg hatchability

To eliminate the carry over effect of the susceptible check cultivar, the insects were reared on the test cultivars as described in para 3.4.2.4.

A pair of newly emerged adults were released on the respective test cultivars at seedling, tillering and booting stages in three separate experiments. The adults were daily transferred to fresh plants of identical age upto five days.

The emerging nymphs were counted and removed regularly. On the eighth day all the plants were cut at the base and examined under a 20 x microscope and the unhatched eggs were counted by dissecting the tissue at the oviposition marks. The total number of eggs laid were arrived at by adding the total number of nymphs emerged and the total number of unhatched eggs counted . The experiment was carried out in completely randamised design and with four replications.

3.4.2.6. Assessment of sex ratio

Ten numbers of newly emerged nymphs, reared on the respective cultivars for one generation as described in para 3.4.2.4 were released on the test cultivars at seedling, tillering and booting stages, in three separate experiments. The insects were transferred to fresh plants of identical age when yellowing symptoms were observed on the plants. The adults emerging on each cultivar were sexed and recorded and the female/male ratio was worked out. The experiments were carried out in completely randomised design and each treatment was replicated four times.

3.4.2.7. Assessment of feeding test

The techniques developed by Sogawa and Pathak (1970) was adopted with suitable modifications for the experiments. The experiment was carried out in seedling,

tillering and booting stages of the test cultivars in three sets of experiments. The methodology described in para 3.4.2.2 was adopted for these experiments. But in place of the black paper, a Watman No.1 filter paper dipped in Bromocresol green solution(1% w/v) and dried was placed on the polyester film disc. It was ensured that the filter paper did not touch water or soil and there was no gap between the culm and filter paper. The plant with the filter paper was enclosed in a polyester film cage as described earlier, leaving no space between the cage and the filter paper. Five number of two day old last instar nymphs obtained from the stock culture were released on each caged plant. Honey dew excreted by the insects falling on the filter paper produced dark blue spots. Twenty four hours after releasing the insects, the filter paper was removed and the area of blue spots was measured by placing a transparent graph paper over the filter paper. The experiments were arranged in completely randomised design, and with four replication for each treatment.

3.5. Effect of crowding on the biology of *S. furcifera*

Thirty day old plants of the test cultivars caged in Polyester film cages, were used for this experiment. On each test cultivar freshly emerged first instar nymphs of *S. furcifera* were released at the rate of 25, 50 and 100 in separate pots. Each treatment was replicated four times. The insects were

transferred to fresh plants of identical age as and when the plants showed yellowing symptoms. The emerging adults were sexed and counted. The number of brachypterous insects were also counted and recorded. The data were analysed treating the experiment as 5 x 3 factorial completely randomised design. Each treatment was replicated four times.

3.6. Assessment of interspecific competition

For this experiment brownplant hopper (Nilaparvata lugens Stal.) collected from paddy fields were reared in the green house on TN-1 plants and a stock culture was maintained using the same method adopted for S. furcifera.

Thirty day old plants of the test cultivars raised in clay pots and caged in polyester film cages were used for the experiment. First instar nymphs/adults of N. lugens and S. furcifera mixed in varying proportions as detailed below were released on each cultivar of rice.

1. 10 first instar nymphs of WBPH and 10 first instar nymphs of BPH
2. 20 " " and 10 " "
3. 10 " " and 20 " "
4. 3 pairs of adult insects of WBPH and 3 pairs of adult insects of BPH.

The insects on the plants were maintained for 60 days to allow the emergence of two generations. The insects were

transferred to fresh plants of identical age as and when yellowing of outer leaves was observed. The total adults formed in the first and second generations S. furcifera and N. lugens were counted and recorded. The data were statistically analysed by treating the experiment as 5 x 2 factorial design with three replications for each treatment.

3.7. Alternate hosts

The common rice land weeds, Echinochloa colona (L.) Link, Fimbristylis miliaceae (L.) Vahl, Cynodon dactylon (L.) Pers, Cyperus iria (L.), Panicum repens (L.) and Brachiaria sp. were selected for testing the acceptibility as alternate hosts by S. furcifera.

3.7.1. Assessment of oviposition

The weed plants were raised in clay pots (15 x 15 cm) filled with soil from wet land paddy fields and caged with polyester film cage (70 x 12 cm). Three gravid female of S. furcifera from the stock culture were released on each caged weed plant. The nymphs emerging on the plants were counted and recorded.

3.7.2. Assessment of nymphal development

Weed plants were raised in clay pots as described in para 3.7.1. Ten numbers of first instar nymphs of S. furcifera were released in the caged weed plant ten days after planting. The emerging adults were counted and recorded.

RESULTS

RESULTS

4.1. Preliminary Screening

The rice cultivars screened for resistance to S. furcifera in this experiment are listed in Table 1. The methods adopted for the preliminary screening were the seed box screening test, free choice and no-choice tests, settling response test and population build up test.

4.1.1. Seed box screening and free choice and no choice tests

The mean score values of damage in the 0-9 scale (Anon, 1980) in the seed box screening test and in the free choice and no choice tests are given in Table 2 and illustrated in Fig. 1a, 1b, and 1c.

4.1.1.1. Seed box screening test

The cultivars showed significant variations in the score values which ranged between 2.20 (Cul 126) and 7.82 (TN-1). The damages in TN-1 and Triveni caused by the pest was significantly higher than the damage in the remaining cultivars and the cultivars Cul 126 and Jyothi were at the other extreme showing significantly lower damage. The damage ratings in Cul 93, Pavizham and Karthika ranged from 4.91 to 5.55 did not differ among themselves significantly but showed significantly lower damage than in TN-1 and Triveni. The damage rating in Ptb 33 was 3.76 which was significantly higher than the damage in Cul 126 andJyothi and lower than the damage in other cultivars (Plate 4).

Table 2. Damage (0-9 scale) of rice cultivars caused by *S. furcifera* when exposed at the seedling stage.

cultivars	damaged rates observed in		
	seed box screening test	free choice test	no choice test
TN-1	7.82 (2.80)^{e}	8.05 (2.84)^{f}	7.59 (2.75)^{e}
Ptb 33	3.76 (1.94)^{b}	4.18 (2.05)^{cd}	2.11 (1.45)^{b}
Cul 93	4.91 (2.22)^{c}	6.22 (2.49)^{e}	3.33 (1.82)^{c}
Triveni	7.10 (2.66)^{d}	5.02 (2.24)^{de}	6.50 (2.55)^{d}
Cul 126	2.20 (1.48)^{a}	2.07 (1.44)^{b}	1.45 (1.20)^{a}
Jyothi	2.47 (1.57)^{a}	1.07 (1.04)^{a}	3.51 (1.87)^{c}
Pavizham	4.96 (2.23)^{c}	4.14 (2.03)^{cd}	3.59 (1.89)^{c}
Karthika	5.55 (2.36)^{c}	3.17 (1.78)^{c}	3.64 (1.91)^{c}

Means in a column followed by a common letter are not significantly diff at 5% level (DMRT). Figures in parenthesis are values transformed as square roots.

Fig.1

a) Seed box screening test

b) Free-choice test

c) No-choice test

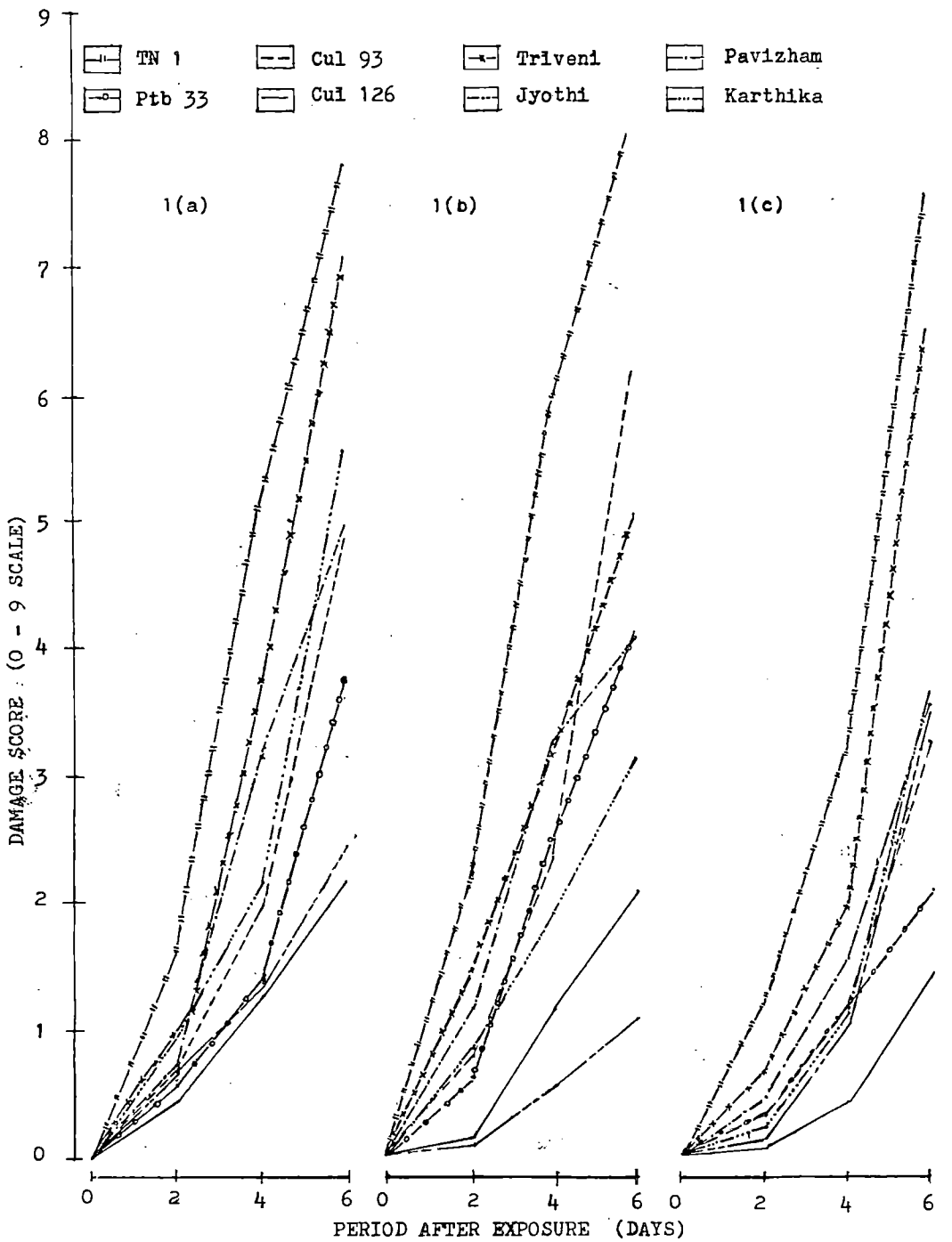


Fig.1 Damage of rice cultivars caused by S.furcifera,when exposed at the seedling stage.

Plate - IV Seed box screening test-different levels of damage to the test cultivar when 90 per cent of TN-1 seedlings were killed.

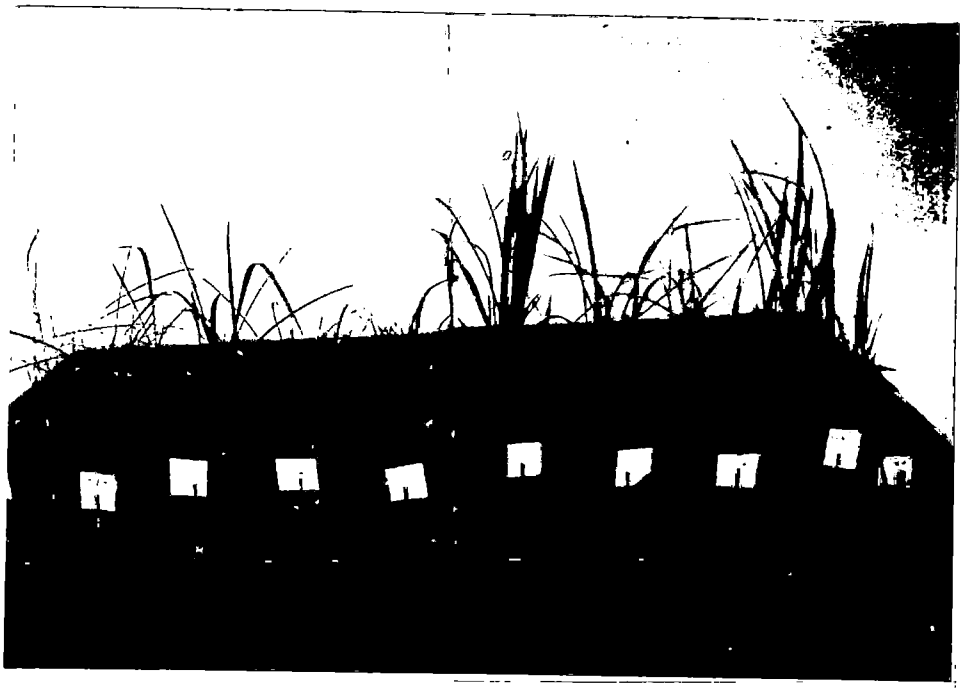


Plate IV

4.1.1.2. Free-choice and no-choice tests

The damage ratings in the free-choice and no-choice tests also showed a trend similar to that of the seed box screening test. In the free-choice test the cultivar Jyothi suffered the lowest damage followed by Cul 126 whereas the highest damage was observed in TN-1. Other cultivars recorded intermediate values.

In the no-choice test, Cul 126 and TN-1 suffered the minimum and maximum damages respectively while the other cultivars had intermediate score values.

4.1.2. Settling behaviour of S. furcifera on seedlings of rice cultivars.

The settling behaviour of second and third instar nymphs of S. furcifera were evaluated at one, eight, twenty four and forty eight hours after release of the insects on the seedlings of the test cultivars , The results are presented in Table 3. The results of the experiment showed significant variations.

The highest number of insects settled was on TN-1, while the minimum number was on Jyothi and Cul 126 and it was followed by Ptb 33. The number of insects settled in Pavizham, Cul 93, Karthika and Triveni were on par. Significant variations were lacking in the number of insects observed at one, eight, twenty four and forty eight hours after release in different cultivars.

Table 5. Settling response of S. furcifera on seedlings of rice cultivars

cultivars	Mean number of nymphs settled per row of plants observed at different intervals after release				
	1h	8h	24h	48h	Mean
TN-1	114.32 (10.74)^{a}	108.97 (10.49)^{a}	113.90 (10.72)^{a}	111.55 (10.61)^{a}	112.17 (10.64)^{a}
Ptb 33	51.31 (7.23)^{cd}	56.49 (7.58)^{bc}	35.54 (6.05)^{de}	49.28 (7.09)^{c}	49.83 (6.99)^{c}
Cul 93	59.30 (7.77)^{bc}	68.53 8.34)^{b}	54.61 (7.46)^{bc}	51.91 (7.27)^{c}	58.42 (7.71)^{bc}
Triveni	68.94 (8.36)^{b}	58.61 (7.72)^{bc}	66.86 (8.24)^{b}	67.86 (8.30)^{b}	65.50 (8.15)^{b}
Cul 126	30.32 (5.60)^{e}	28.66 (5.45)^{d}	44.67 (6.76)^{cd}	33.32 (5.86)^{d}	33.98 (5.91)^{d}
Jyothi	45.45 (6.82)^{d}	31.41 (5.69)^{d}	27.56 (5.34)^{e}	27.09 (5.30)^{d}	32.50 (5.79)^{d}
Pavizham	51.31 (7.23)^{cd}	61.66 (7.92)^{bc}	54.88 (7.48)^{bc}	64.57 (8.10)^{b}	57.99 (7.68)^{bc}
Karthika	65.27 (8.14)^{b}	51.18 (7.22)^{c}	63.28 (8.02)^{b}	70.24 (8.44)^{b}	62.29 (7.95)^{b}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT). Figures in parenthesis are values transformed as square roots.

4.1.3. Population build up test of *S. furcifera* on rice cultivars

The results of the population build up test are presented in Table 4 and depicted in Figure 2. The cultivar TN-1 favoured the development of the insects most while the build up was least on Cul 126 in the counts taken at 10, 20, 30, 40, 50 and 60 days after the release of insects. Other than Cul 126, Jyothi was the least favoured for the population build up as observed at 10, 50 and 60 days after release of the insects whereas in the counts at 20 and 30 days after release, the cultivar Cul 93 was on par with Jyothi. Other than TN-1, the cultivars Pavizham and Triveni favoured the multiplication of the insects as shown by the counts taken at 20, 30, 40 and 60 days after release.

The results of the preliminary screening trial ie., seed box screening test, free choice test and no choice tests orientation settling response test and population build up test are presented in Table 5. Based on the results of the above experiments the cultivars were classified into 4 groups namely resistant, moderately resistant, susceptible and highly susceptible. The cultivars Cul 126 and Jyothi from the resistant group, Pavizham and Karthika from the moderately resistant group and highly susceptible TN-1 were selected for studying the mechanismsof resistance.

Table 4. Population build up of *S. furcifera* on different cultivars when released on 30 day old plants.

cultivars	Mean number of insects observed at different intervals after release (days)					
	10	20	30	40	50	60
TN-1	322.42 (17.90)^{a}	267.90 (16.40)^{a}	224.25 (15.01)^{a}	813.67 (28.54)^{a}	728.46 (27.01)^{a}	641.47 (25.35)^{a}
Ptb 33	146.40 (12.14)^{c}	97.48 (9.92)^{cd}	57.68 (7.66)^{c}	118.48 (10.93)^{f}	113.30 (10.68)^{b}	66.42 (8.21)^{c}
Cul 93	212.60 (14.62)^{b}	78.70 (8.93)^{d}	48.99 (7.09)^{c}	142.40 (11.98)^{de}	88.70 (9.47)^{c}	72.09 (8.55)^{bc}
Triveni	212.60 (14.62)^{b}	151.39 (12.34)^{b}	86.37 (9.35)^{b}	186.90 (13.71)^{b}	88.64 (9.47)^{c}	83.91 (9.21)^{b}
Cul 126	93.59 (9.73)^{d}	53.17 (7.36)^{e}	25.51 (5.15)^{d}	76.38 (8.80)^{g}	33.88 (5.91)^{e}	21.58 (4.75)^{e}
Jyothi	104.89 (10.29)^{d}	83.21 (9.18)^{d}	53.51 (7.38)^{c}	130.20 (11.45)^{e}	61.48 (7.90)^{d}	52.34 (7.30)^{d}
Pavizham	206.10 (14.39)^{b}	141.50 (11.94)^{b}	90.76 (9.58)^{b}	168.28 (13.01)^{bc}	124.48 (11.20)^{b}	83.33 (9.18)^{b}
Karthika	155.54 (12.51)^{c}	110.54 (10.54)^{c}	59.24 (7.76)^{c}	147.31 (12.19)^{cd}	89.26 (9.50)^{c}	69.66 (8.41)^{bc}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT). Figures in parenthesis are values transformed as square roots.

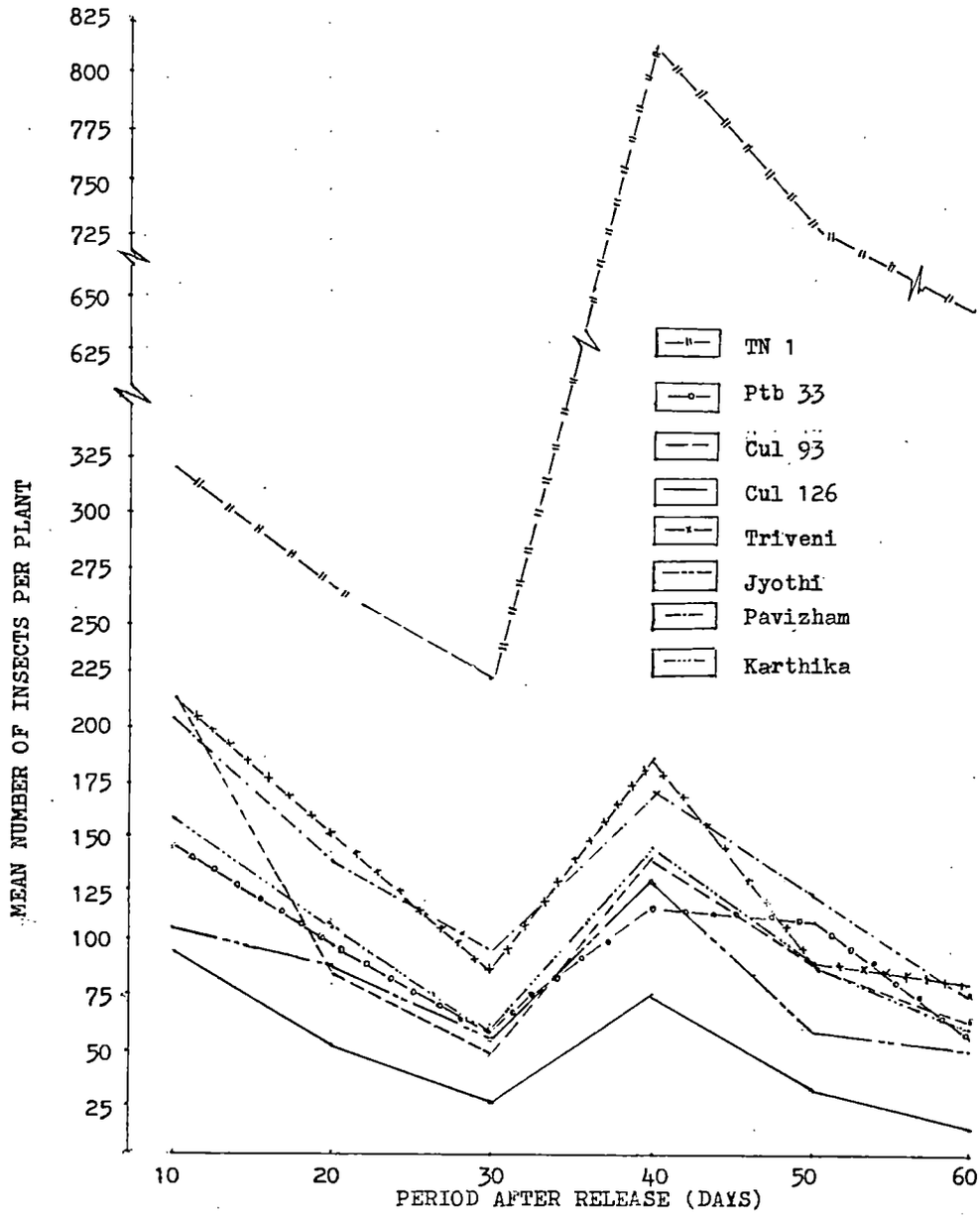


Fig.2 Population build up of S.furcifera, when three pairs of the insects were released on thirty day old plants .

Table 5. Results of the preliminary screening trials for resistence to *S. furcifera* on rice cultivars.

	Score value (0-9 scale)			Population count after 60 days of release
	seed box screening test	free-choice test	no-choice test	
Resistance (0-3)				
Cul 126	2.20	2.07	1.45	21.58
Jyothi	2.47	1.07	3.51	52.34
Moderately resistant (3.1-5)				
Ptb 33	3.76	4.18	2.11	66.42
Cul 93	4.91	6.22	3.33	72.09
Pavizham	4.96	4.14	3.59	83.33
Karthika	5.55	3.17	3.64	69.66
Susceptible (5.1-7)				
Triveni	7.10	5.02	6.50	83.91
Highly susceptible (7.1-9)				
TN-1	7.82	8.05	7.59	641.47

4.2. Mechanisms of resistance

4.2.1. Ovipositional preference

Significant difference was noticed on the number of eggs laid by S. furcifera on the rice cultivars. The preference to oviposition was ascertained by the mean numbers of eggs laid on the leaf sheath and leaf blade separately and together. Table 6 summarises the results of the experiment.

4.2.1.1. Total number of eggs

The S. furcifera laid eggs on all the test cultivars. The highest egg count was observed in TN-1 plants, with a mean value of 113.48. The lowest number was observed in Cul 126 followed by Jyothi the mean numbers being 39.45 and 46.96 respectively. The number of eggs in Pavizham and Karthika were significantly higher than those on Jyothi and and lower than TN-1, the difference between the two being insignificant.

4.2.1.2. Eggs in the leaf sheath

In all the cultivars more number of eggs were observed in leaf sheath than in leaf blade. The highest number of eggs were found in TN-1 and the lowest was in Cul 126 the numbers being 98.6 and 31.42 respectively. The number of eggs in Jyothi, Pavizham and Karthika were on par, but they varied significantly from those of TN-1 and Cul 126.

4.2.1.3. Eggs in the leaf blade

The number of eggs in the leaf blade ranged between 7.95 and 16.95 and the number was the lowest in Cul 126 and

Table 6. Ovipositional preference of S. furcifera on rice cultivars

cultivars	mean number of eggs observed per plant		
	leaf sheath	leaf blade	Total
TN-1	98.60 (9.93)^{c}	14.13 (3.76)^{b}	113.48 (10.65)^{d}
Pavizham	44.93 (6.70)^{b}	13.85 (3.72)^{b}	59.18 (7.69)^{c}
Karthika	42.11 (6.49)^{b}	16.95 (4.12)^{b}	59.17 (7.69)^{c}
Jyothi	38.45 (6.20)^{b}	8.46 (2.91)^{a}	46.96 (6.85)^{b}
Cul 126	31.42 (5.61)^{a}	7.95 (2.82)^{a}	39.45 (6.28)^{a}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT). Figures in parenthesis are values transformed as square roots.

the highest in Karthika.

4.2.2. Assessment of antibiosis

4.2.2.1. Nymphal duration

The total and instar-wise mean nymphal duration of S. furcifera when reared on different rice cultivars and at the three growth stages of the crop (seedling, tillering and booting) are summarised in Table 7.

In the seedling stage the total nymphal duration of the insect when reared on Jyothi, Cul 126 and Karthika were 14.00, 13.50 and 13.33 days respectively and they were on par. Duration of 12.17 days was recorded on Pavizham which was significantly lower than the above three. A total duration of 10.83 days was observed on TN-1 which was significantly lower than the duration on the other cultivars.

There was no variation among the cultivars in the seedling stage influencing the duration of first, second and fifth instars, whereas in the third instar, the insects from TN-1 recorded significantly lower duration as compared to thos reared on other cultivars. Duration of the fourth instar on TN-1 was shorter than reared on other cultivars except on Pavizham.

In the tillering stage also the total nymphal duration was the highest on Cul 126 and it was followed by Jyothi, the values being 15.5 and 15.0 days respectively. The lowest

Table 7. Effect of rice cultivars on the nymphal duration of S. furcifera when reared on different growth stages of the crop.

cultivars	nymphal duration in days observed on plants at																	
	seedling stage						tillering stage						booting stage					
	1st instar	2nd instar	3rd instar	4th instar	5th instar	total	1st instar	2nd instar	3rd instar	4th instar	5th instar	total	1st instar	2nd instar	3rd instar	4th instar	5th instar	total
TN-1	2.17^{a}	2.17^{a}	2.17^{b}	2.33^{b}	2.00^{a}	10.83^{c}	2.00^{c}	2.50^{a}	2.67^{b}	2.33^{b}	2.17^{b}	11.67^{c}	2.00^{b}	2.83^{a}	3.00^{c}	3.00^{b}	2.00^{c}	12.83^{d}
Paviznam	2.17^{a}	2.17^{a}	3.00^{a}	2.83^{ab}	2.00^{a}	12.17^{b}	2.50^{b}	2.17^{a}	3.00^{b}	2.17^{b}	2.00^{b}	11.83^{c}	2.33^{b}	2.33^{a}	3.83^{b}	3.17^{b}	2.00^{c}	13.67^{cd}
Karthika	2.50^{a}	2.67^{a}	3.00^{a}	3.17^{a}	2.00^{a}	13.33^{a}	2.33^{bc}	2.50^{a}	3.67^{a}	3.17^{a}	2.33^{ab}	14.00^{b}	2.17^{b}	2.50^{a}	3.83^{b}	3.50^{b}	2.50^{bc}	14.50^{c}
Jyothi	2.50^{a}	2.33^{a}	3.67^{a}	3.33^{a}	2.17^{a}	14.00^{a}	3.00^{a}	2.33^{a}	3.67^{a}	3.83^{a}	2.17^{ab}	15.00^{a}	3.00^{a}	2.67^{a}	3.50^{bc}	4.00^{a}	2.67^{ab}	15.83^{b}
Cul 126	2.17^{a}	2.33^{a}	3.17^{a}	3.50^{a}	2.33^{a}	13.50^{a}	3.00^{a}	2.67^{a}	3.83^{a}	3.17^{a}	2.83^{a}	15.50^{a}	3.00^{a}	3.00^{a}	4.67^{a}	4.17^{a}	3.33^{a}	18.17^{a}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT).

duration was observed on TN-1 and the duration on Pavizham did not vary significantly from that of TN-1. The insects from Karthika showed values in between the above two groups of cultivars. Duration of different instars of the insects developed on cultivars at the tillering stage also showed similar trend except in the case of second instar, where there was no significant variations among the cultivars.

In the booting stage the total nymphal duration was the highest on Cul 126 (18,17 days) and it was followed by Jyothi (15.83 days). The duration on TN-1 and Pavizham were 12.83 and 13.67 respectively which were on par and shorter than those on other cultivars. The duration on Karthika was 14.5 days which was significantly higher than that of TN-1 and lower than that of Cul 126 and Jyothi. The instar wise duration also showed a trend more or less similar to the total duration except in second instar nymphs where there was no difference among cultivars.

4.2.2.2. Nymphal survival

The mean percentage survival of the nymphs of S. furcifera when reared on three growth stages of the test cultivars is presented in Table 8. In the seedlings stage, the highest mean percentage survival of S. furcifera was observed on TN-1 (87.77%) while the lowest value was observed on Cul 126, (50%) which was on par with those of Jyothi and Karthika. The mean survival percentage o Pavizham was 62.67 which was significantly lower than that of TN-1 but was on par with those of Karthika and Jyothi.

Table 8. Effect of rice cultivars on the nymphal survival and sex ratio of adults of *S. furcifera* when reared on different growth stages of the crop.

cultivars	seedling stage		tillering stage		booting stage	
	nymphal survival (%)	sex ratio	nymphal survival (%)	sex ratio	nymphal survival (%)	sex ratio
TN-1	87.77 (69.50)^{a}	0.90^{a}	85.36 (67.47)^{a}	0.83^{a}	75.17 (60.09)^{a}	0.78^{a}
Pavizham	62.67 (52.32)^{b}	0.51^{b}	55.03 (47.87)^{b}	0.51^{b}	50.00 (44.98)^{b}	0.46^{b}
Karthika	57.52 (49.31)^{bc}	0.51^{b}	50.00 (44.98)^{b}	0.46^{b}	44.97 (42.10)^{b}	0.44^{b}
Jyothi	55.03 (47.86)^{bc}	0.48^{b}	50.00 (44.98)^{b}	0.48^{b}	44.97 (42.10)^{b}	0.48^{b}
Cul 126	50.00 (44.98)^{c}	0.46^{b}	36.96 (37.43)^{b}	0.46^{b}	27.38 (31.54)^{c}	0.43^{b}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT). Figures in parenthesis are values transformed as angles.

The mean percentage survival of the insects reared on test cultivars at the tillering stage also showed a trend similar to that in the seedling stage. The highest value of 85.36 per cent was observed on TN-1 which was significantly higher than that in the other cultivars. The lowest value of 36.96 per cent was observed on Cul 12(There was no significant variation in the survival rate o1 nymphs on the cultivars Pavizham, Karthika, Jyothi and Cul 126.

The mean percentage survival was the highest on TN-1 (75.17) at the booting stage while the lowest value of 27.38 per cent was found on Cul 126. The survival percentage on Pavizham, Karthika and Jyothi were on par and was significantly higher than that on Cul 126 and significantly lower than on TN-1.

4.2.2.3. Sex ratio

The female/male ratio of the adults reared on the test cultivars at the three growth-stages are presented in Table 8. It can be seen from the table that a significantly higher female/male ratio was found in all the three growth stages when the insects were reared on TN-1. The sex ratio of the insects did not show any variation when the insects were reared on the other four cultivars.

4.2.2.4. Adult longevity

The mean adult longevity of males and females of S. furcifera when reared at the seedling, tillering and

booting stages of the rice cultivars are presented in Table 9. Statistical analysis revealed that the adult longevity of the insect was significantly different among the test cultivars and at the three growth stages.

The female adults lived for significantly higher period than when reared on TN-1 at the seedling, tillering and booting stages, the durations being 19.00, 18.25 and 18.00 days respectively. In the seedling stage the longevity of the female adult was on par on Pavizham, Karthika, Jyothi and Cul 126. In the tillering and booting stages, the life span of females were on par on Pavizham, Karthika and Jyothi while the longevity on Cul 126 was significantly lower than on Pavizham.

The longevity of males in general was shorter than the females. In the seedling stage male longevity ranged from 5.5 days (Cul 126) to 13.00 days (TN-1), the values being significantly lower and higher respectively from those of other cultivars. In the tillering and booting stages the male longevity on TN-1 was 9.25 and 8.25 days respectively, which was significantly higher than those on other cultivars. The male longevity on other cultivars did not show any variation both in the tillering and booting stages.

4.2.2.5. Fecundity

The mean number of eggs laid and the hatching percentage of eggs of S. furcifera when reared at three growth stages

Table 9. Effect of rice cultivars on the adult longevity of males and females of *S. furcifera* when reared on different growth stages of the crop.

cultivars	longevity in days at					
	seedling stage		tillering stage		booting stage	
	females	males	females	males	females	males
TN-1	19.00[a]	13.00[a]	18.25[a]	9.25[a]	18.00[a]	8.25[a]
Pavizham	11.00[b]	8.50[b]	13.25[b]	6.00[b]	9.75[bc]	5.25[b]
Karthika	10.25[b]	6.25[cd]	11.25[bc]	5.00[b]	10.00[bc]	4.75[b]
Jyothi	10.00[b]	7.50[bc]	11.75[bc]	5.00[b]	9.50[bc]	4.25[b]
Cul 126	9.75[b]	5.50[d]	10.75[c]	5.25[b]	9.25[c]	4.00[b]

Means in a column followed by a common letter are not significantly different at 5% level (DMRT).

of the test cultivars are presented in Table 10. Analysis of variance of the data showed that there was significant variation in the number of eggs laid and in the hatching percentage of the eggs when the insects was reared at the three growth stages of the test cultivars.

In the seedling stage significantly higher number of eggs were laid by insects reared on TN-1 (68.88), whereas the number of eggs laid by insects reared on Pavizham, Karthika, Jyothi and Cul 126 were 36.67, 42.13, 33.68 and 36.94 respectively and were on par.

Comparatively higher number of eggs were seen laid by the insects reared at the tillering and booting stages of all the cultivars. In the tillering stage, the highest number recorded was 276.06 on TN-1 which was significantly higher than in other cultivars. The lowest number of eggs was 174.40 in Cul 126, but the number of eggs did not differ significantly from those of Pavizham, Karthika and Jyothi.

In the booting stage also the highest number of eggs were laid on TN-1 (264.10) followed by Karthika (148.13). The lowest number was in Jyothi (99.39) which did not differ from that of Pavizham and Cul 126.

4.2.2.6. Hatchability

The hatching percentage of the eggs laid by S. furcifera on different rice cultivars, at three growth stages of the

Table 10. Effect of rice cultivars on the fecundity and hatching percentage of eggs of S. furcifera when reared on different growth stages of the crop.

cultivars	seedling stage		tillering stage		booting stage	
	mean no. of eggs laid *	hatching percentage **	mean no. of eggs laid *	hatching percentage **	mean no. of eggs laid *	hatching percentage **
TN-1	68.88 (8.30)^{a}	98.23 (82.32)^{a}	276.06 (16.62)^{a}	99.30 (85.16)^{a}	264.10 (16.25)^{a}	98.45 (82.82)^{a}
Pavizham	36.67 (6.22)^{b}	96.20 (78.73)^{a}	189.47 (13.76)^{b}	92.77 (74.37)^{b}	118.65 (10.89)^{c}	94.77 (76.75)^{bc}
Karthika	42.13 (6.49)^{b}	95.94 (78.34)^{a}	211.45 (14.54)^{b}	95.89 (78.27)^{ab}	148.53 (12.19)^{b}	96.31 (78.60)^{ab}
Jyothi	33.68 (5.80)^{b}	94.21 (76.04)^{a}	186.62 (13.66)^{b}	89.20 (70.79)^{b}	99.39 (9.97)^{c}	92.19 (73.75)^{bc}
Cul 126	36.94 (6.08)^{b}	97.57 (81.00)^{a}	174.40 (13.21)^{b}	87.43 (69.21)^{b}	113.52 (10.65)^{c}	90.92 (72.43)^{c}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT).

* Figures in parenthesis are values transformed as square roots.

** Figures in parenthesis are values transformed as angles.

crop are presented in Table 10.

In the seedling stage the hatching percentage of eggs in the test cultivars did not show significant variation whereas it varied among cultivars at the tillering and booting stages.

In the tillering stage the hatching percentage in TN-1 was 99.30 which was significantly higher than those of other test cultivars except Karthika. The hatching percentage on Pavizham, Karthika, Jyothi and Cul 126 were 92.77, 95.89, 89.20 and 87.43 respectively. In the booting stage also the highest hatching percentage (98.45) was observed in TN-1 which did not differ significantly from that of Karthika. The lowest hatching percentage (90.92) was found on Cul 126 which did not vary significantly from that of Pavizham and Jyothi.

4.2.2.7. Feeding rate

Feeding rate of S. furcifera in the three growth stages of the test cultivars as indicated by the mean area of honey dew spots, are presented in Table 11. There was significant variation in the feeding rate on different cultivars as well as in different growth stages.

In the seedling stage, the highest value of 104.94 mm^2 of honey dew spot was observed when fed on TN-1 which was significantly higher than those observed in other cultivars.

Table 11. Effect of rice cultivars on the feeding rates of S. furcifera when reared on different growth stages of the crop.

cultivars	mean area of honey dew spots (mm^2)		
	seedling stage	tillering stage	booting stage
TN-1	104.94 (10.24)[a]	130.18 (11.41)[a]	121.23 (11.01)[a]
Pavizham	51.73 (7.19)[b]	60.72 (7.79)[b]	55.90 (7.34)[b]
Karthika	53.94 (7.34)[b]	55.80 (7.47)[bc]	52.72 (7.26)[b]
Jyothi	47.97 (6.93)[b]	56.24 (7.50)[bc]	50.22 (7.09)[bc]
Cul 126	49.23 (7.02)[b]	51.23 (7.16)[c]	46.75 (6.84)[c]

Meansin a column followed by a common letter are not significantly different at 5% level (DMRT). Figures in parenthesis are values transformed as square roots.

The honey dew spot area produced by insects fed on other cultivars in the seedling stage varied from 53.94 mm^2 (Karthika) to 47.97 mm^2 (Jyothi) but they were not significantly different.

In the tillering and booting stages the area of honey dew spots produced by insects fed on TN-1 was 130.18 mm^2 and 121.23 mm^2 respectively which were significantly higher than those in other test cultivars. The area of honey dew spots varied from 60.72 (Pavizham) to 51.23 mm^2 (Cul 126) in tillering stage and from 53.9 mm^2 (Pavizham) to 46.75 mm^2 (Cul 126) in the booting stage.

4.3. Effect of crowding on nymphal survival, sex ratio and brachyptery.

4.3.1. Nymphal survival

The effect of crowding of *S. furcifera* nymphs on the percentage survival on different test cultivars are presented in Table 12 and illustrated in Figure 3.

When the insects were released at the rate of 25 per plant, the percentage of nymphal survival was the highest (80.39%) on TN-1. The percentage survival on Pavizham, Karthika, Cul 126 and Jyothi were 56.05, 58.08, 46.98 and 51.00 respectively and they were on par.

Table 12. Effect of crowding of S. furcifera on percentage survival of nymphs sex ratio of adults and percentage of brachypterous females when reared on different rice cultivars.

cultivars	percentage of nymphal survival with initial population of (per plant)			sex ratio of adults emerging from the initial population of (per plant)			mean percentage of brachypterous females observed with initial population of (per plant)		
	25	50	100	25	50	100	25	50	100
TN-1	80.39 (63.69)^{a}	73.27 (58.85)^{a}	61.44 (51.59)^{a}	1.89^{a}	1.78^{a}	1.78^{a}	66.08 (54.36)^{a}	51.47 (45.82)^{a}	45.50 (42.40)^{a}
Pavizham	56.05 (48.46)^{b}	50.00 (44.98)^{b}	32.60 (34.80)^{b}	0.66^{b}	0.61^{b}	0.52^{b}	29.29 (32.75)^{b}	24.21 (29.46)^{ab}	14.69 (22.53)^{ab}
Karthika	58.08 (49.63)^{b}	51.02 (45.57)^{b}	33.28 (35.22)^{b}	0.63^{b}	0.51^{b}	0.56^{b}	26.37 (31.28)^{b}	22.80 (28.51)^{ab}	17.04 (24.37)^{ab}
Jyothi	51.00 (45.55)^{b}	43.99 (41.53)^{b}	29.25 (32.73)^{b}	0.53^{b}	0.48^{b}	0.49^{b}	16.30 (23.81)^{b}	16.10 (23.64)^{b}	7.95 (16.37)^{b}
Cul 126	46.98 (43.25)^{b}	38.93 (38.59)^{c}	25.73 (30.46)^{b}	0.51^{b}	0.50^{b}	0.45^{b}	18.04 (25.12)^{b}	16.48 (23.94)^{b}	10.42 (18.83)^{b}

Means in a column followed by a common letter are not significantly different at 5% level (DMRT).
Figures in parenthesis are values transformed as angles.

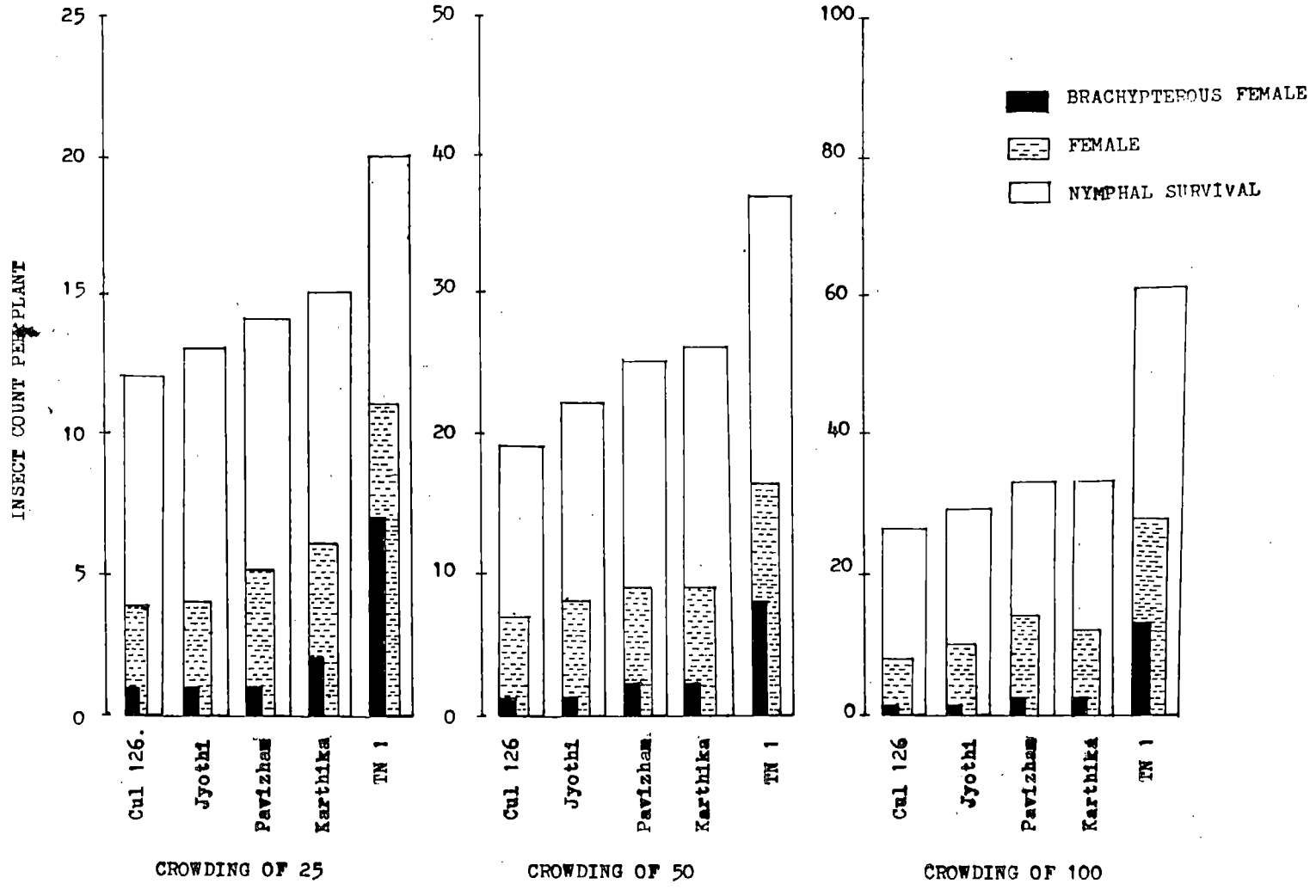


Fig.3 Effect of crowding on nymphal survival and development of females and brachyptery

When the insects were released at the rate of 50 per plant, TN-1 recorded the highest percentage nymphal survival (73.27). The values in Cul 126 was the lowest (38.93). The values in Jyothi, Pavizham and Karthika were 43.99, 50.00 and 51.02 respectively which were significantly higher than that on Cul 126 and significantly lower than the percentage on TN-1.

Among the cultivars, TN-1 recorded the highest nymphal survival (61.44%), when the nymphs were released at the rate of 100 nymphs per plant, the values were on par in the other test cultivars which ranged between 33.28 (Karthika) and 25.73 (Cul 126).

On TN-1 the percentage survival was 80.39, 73.27 and 61.44 when the nymphs were released at the rates of 25,50 and 100 respectively. The survival was significantly lower when the nymphs were released at the rate of 100 per plant as compared to the rate of 25 and 50 numbers per plant and they were on par. On other cultivars also the rate of 100 numbers per plant resulted in significantly lower survival than at the rate of 25 and 50 per plant.

4.3.2. Effect of the crowding of nymphs on the sex ratio of emerging adults.

The data of the experiment are presented in Table 12 and illustrated in Figure 3.

The female/male ratio was significantly higher on TN-1 as compared to other cultivars when the nymphs were released at 25,50 and 100 per plant. The sex ratios were on par on the remaining cultivars. When each cultivar was considered significant variation in the sex ratio was not observed.

4.3.3. Effect of crowding on the percentage of brachypterous adults in emerging population.

The mean percentage of brachypterous adults developed when the nymphs were released at the rates of 25, 50 and 100 per plant are presented in Table 12 and illustrated in Figure 3.

The highest percentage of brachypterous forms was observed on TN-1 at the crowding ratesof 25,50 and 100 per plant and the values were 66.08, 51.47 and 45.50 respectively. The mean percent values in the other cultivars ranged between 16.30 (Jyothi) to 29.29 (Pavizham) when crowded at the rate of 25 per plant between 16.1 (Jyothi) to 24.21 (Pavizham) when crowded at the rate of 50 per plant and between 7.95 (Jyothi) and 17.04 (Karthika) when crowded at the rate of 100 numbers. The values were on par at the three levels of population.

When each cultivar was considered separately it was clearly found that crowding at different rates tried has no influence on the development of brachyptery.

4.4. Interspecific competition between S. furcifera (WBPH) and N. lugens (BPH).

The population build up of WBPH and BPH when released at different proportions of the two species on the test cultivars was studied. The mean numbers of the two species observed at 60th day after release are presented in Table 13 and illustrated in Figure 4a, 4b, 4c and 4d.

4.4.1. Ten first instar nymphs each of WBPH and BPH

There was significant difference in the numbers of insects of two species developed on the rice cultivars. In all the cultivars the BPH population was higher as compared to WBPH. The population of WBPH ranged between 44.64 (TN-1) and 9.66 (Cul 126), whereas the population of BPH ranged between 69.32 (TN-1) and 32.97 (Cul 126).

4.4.2. Twenty WBPH + 10 BPH first instar nymphs

Even when 20 WBPH and 10 BPH nymphs were initially released the population of BPH ranged between 84.31 (TN-1) and 46.21 (Cul 126) whereas the population of WBPH was between 59.3 (TN-1) and 19.97 (Cul 126). The population of BPH was higher as compared to WBPH in all the other test cultivars.

The population of WBPH in Jyothi, Karthika and Pavizham were 27.51, 26.40 and 27.56 respectively which were on par, but higher than on Cul 126 and lower than on TN-1.

Table 13. Population build up of *S. furcifera* and *N. lugens* as observed at 60 day after release, when the two species were reared together on 30 day old plants in different proportions.

cultivars	mean number of insects observed with the initial populations of WBPH and BPH at proportions							
	10 + 10 (nymphs)		20 + 10 (nymphs)		10 + 20 (nymphs)		3 pairs + 3 pairs (adults)	
	WBPH	BPH	WBPH	BPH	WBPH	BPH	WBPH	BPH
TN-1	44.64 (6.68)	69.32 (8.33)	59.30 (7.70)	84.31 (9.18)	54.64 (7.39)	103.75 (10.19)	58.37 (7.64)	123.79 (11.10)
Pavizham	12.65 (3.55)	39.65 (6.30)	27.56 (5.25)	56.61 (7.52)	19.60 (4.43)	45.51 (6.75)	25.97 (5.10)	46.99 (6.86)
Karthika	11.63 (3.41)	43.30 (6.58)	26.40 (5.14)	51.32 (7.16)	19.63 (4.43)	49.86 (7.06)	20.54 (4.53)	51.43 (7.17)
Jyothi	10.66 (3.27)	39.00 (6.24)	27.51 (5.25)	46.28 (6.80)	14.90 (3.86)	26.55 (5.15)	22.95 (4.79)	33.18 (5.76)
Cul 126	9.66 (3.11)	32.97 (5.74)	19.97 (4.47)	46.21 (6.80)	14.97 (3.87)	34.25 (5.85)	17.99 (4.24)	25.25 (5.03)
CD	0.30	0.30	0.72	0.72	0.66	0.66	0.77	0.77

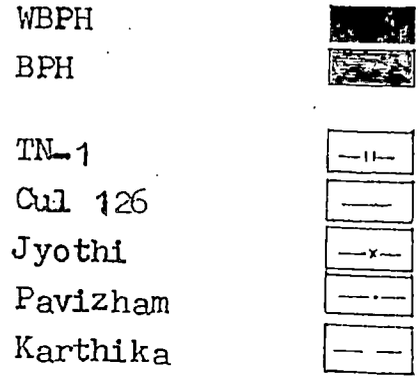
Figures in parenthesis are values transformed as square roots.

Fig.4:

(a) 10 first instar nymphs of WBPH and 10 first instar nymphs of BPH

(b) 20 first instar nymphs of WBPH and 10 first instar nymphs of BPH

(contd...)



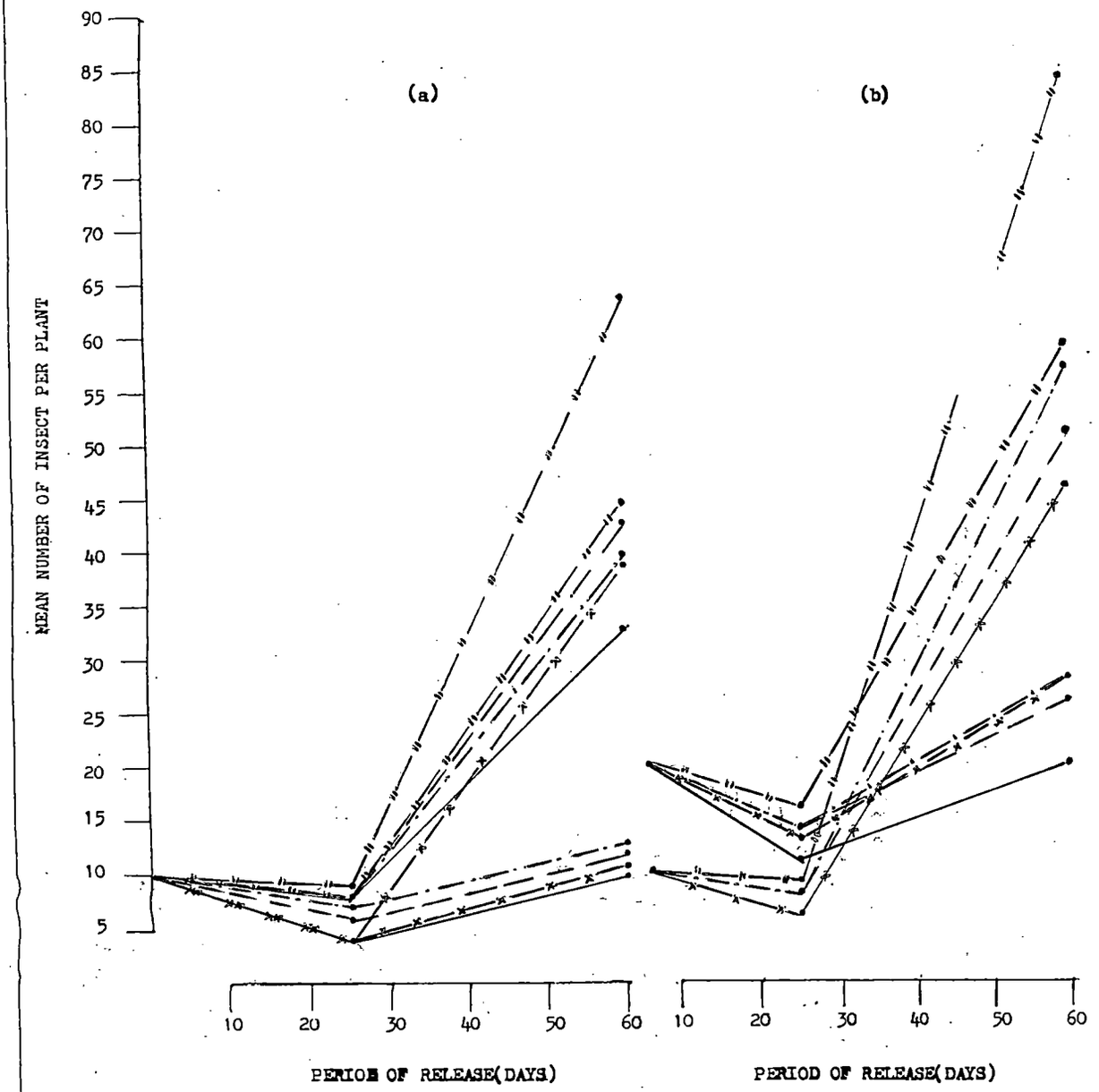
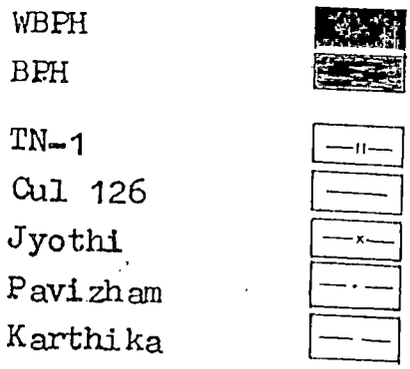


Fig.4 Population build up of S.furcifera and N.lugens at 60 days after release, when the two species were released together in different proportions.

Fig. 4 (contd ...)

(c) 10 first instar nymphs of WBPH and 20 first instar nymphs of BPH

(d) 3 pairs of adult WBPH and 3 pairs of adult BPH



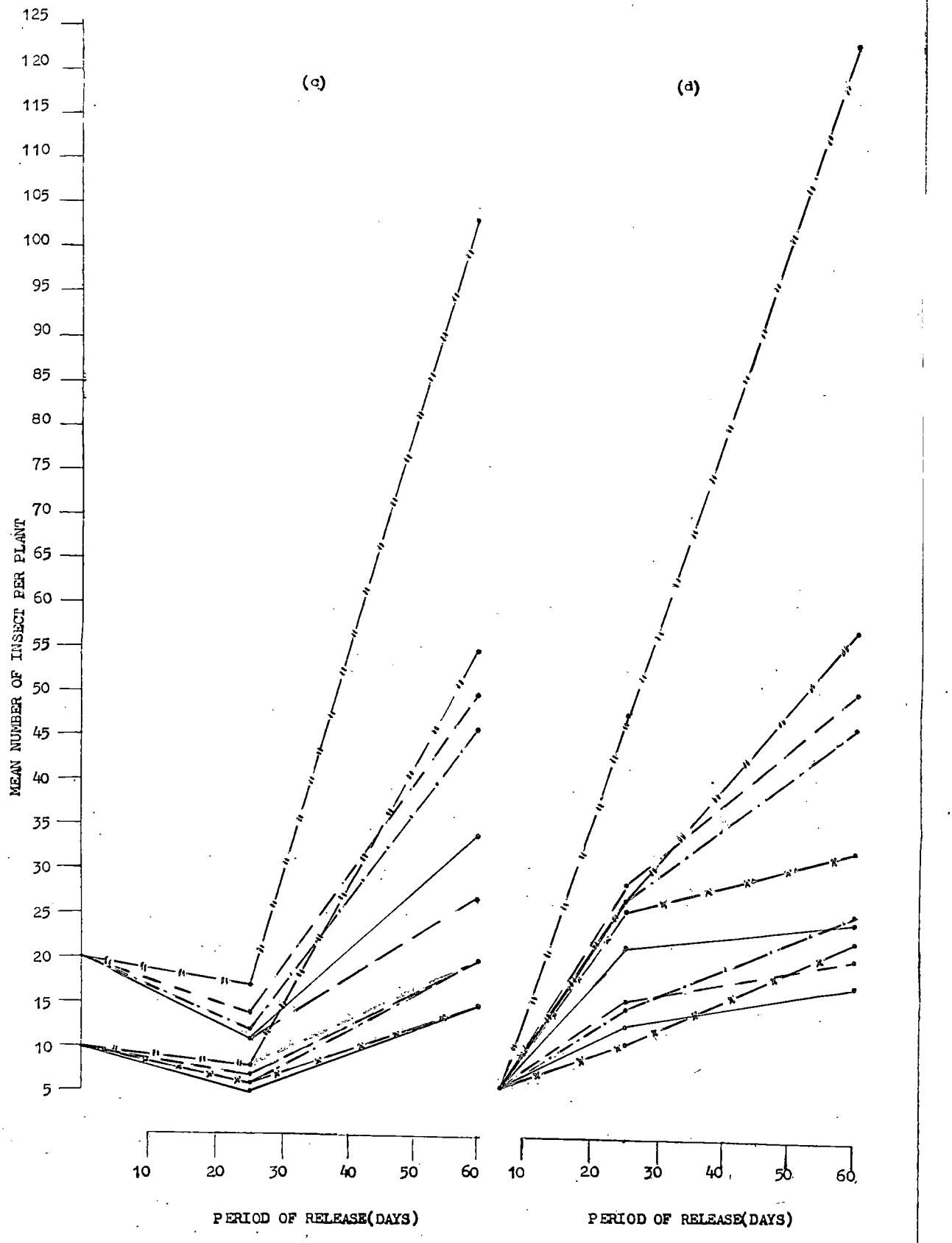


Fig.4 Population build up of S.furcifera and N.lugens at 60 days after release, when the two species were released together in different proportions.

BPH recorded the highest population on TN-1 whereas those in other cultivar were on par.

4.4.3. Ten first instar nymphs of WBPH + 20 first instar nymphs of BPH.

When 10 WBPH and 20 BPH nymphs were initially released, the population of WBPH ranged between 54.64 (TN-1) and 14.90 (Jyothi). Significantly higher population was built up on TN-1 (54.64) whereas the population in other cultivars ranged between 14.90 and 19.63 which were on par.

The population of BPH was higher in all the cultivars as compared to WBPH and it ranged between 103.75 (TN-1) and 26.55 (Jyothi). The population in Cul 126 was 34.25 which was significantly higher than that in Jyothi. The population in Pavizham and Karthika was 45.51 and 49.86 and were on par.

4.4.4. Three pairs adults each of WBPH and BPH

When 3 pairs of adults of each of WBPH and BPH were initially released, BPH maintained its numerical superiority and the population ranged between 123.79 (TN-1) and 25.25 (Cul 126) whereas the population of WBPH was between 58.37 (TN-1) and 17.99 (Cul 126).

TN-1 accounted for significantly higher population of WBPH and BPH than the other cultivars. The WBPH population on Cul 126, Jyothi and Karthika was 17.99, 22.95 and 20.54

Table 14. Mean percentage of nymphal survival, nymphal duration and adult longevity of *S. furcifera* reared on rice land weeds.

Weed plants	nymphal survival (%)	nymphal period (days)		adult longevity (days)	
		male	female	male	female
1. *Echinochloa colona*	40	18.14	23.00	2.57	5.00
2. *Cynodon dactylon*	nil	nil	nil	nil	nil
3. *Panicum repens*	25	20.85	nil	2.40	nil
4. *Brachiaria* sp.	nil	nil	nil	nil	nil
5. *Fimbrystylis miliacae*	nil	nil	nil	nil	nil
6. *Cyperus iria*	nil	nil	nil	nil	nil

DISCUSSION

DISCUSSION

The white-backed plant hopper S. furcifera hitherto recognised as a minor pest of rice is slowly gaining importance as a serious threat to the rice cultivation in India and severe damage to rice crop by the pest has been reported by many workers (Mahar et al., 1978; Gyawalli, 1983; Dhaliwal and Jaswanth Singh, 1983; Gubbaiah et al., 1987; Inayatullah et al., 1987). The pest has made its appearance in the important rice tracts of Kerala, especially in areas where high yielding varieties are under cultivation. The potential of this pest to assume the status of a major pest in areas where rice varieties resistant to N. lugens are grown on a large scale has been indicated (Mochida et al., 1982). To counter this possibility it is essential to have varieties resistant to both N. lugens and S. furcifera. As a first step in this direction it is essential to identify varieties resistant to S. furcifera from among those released as resistant to N. lugens.

The cultivars chosen for the investigation were Jyothi, Thriveni, Karthika, Pavizham, Cul 93, Cul 126, Ptb 33 and TN-1. The variety TN-1, was included as a susceptible check variety. Among the others Jyothi, Thriveni, Karthika and Pavizham are high yielding cultivars widely cultivated in Kerala, and the two cultures, Cul 93 and Cul 126 are very promising high

yielding types. The cultivar Ptb 33 which is a pure-line selection from Arikarai has been internationally accepted as resistant to different biotypes of N. lugens (Anon, 1976a).

Seed box screening following the 0-9 scoring system and studies on the orientation and settling response and population build up of the pest were carried out for a preliminary screening of theeight cultivars. The first two were done in the seedling stage and the third one on 30 day old plants of the test cultivars.

In the seedbox screening TN-1 recorded the highest damage and the cultivars Cul 126 and Jyothi recorded the lowest damage indicating high susceptibility of the former and high resistance of the latter. The cultivars Karthika Pavizham and Ptb 33 showed moderate levels of resistance. The seed box screening test with the same scoring system was repeated in two more trials as free-choice and no-choice tests. Here also the damage ratings were almost similar to those in the seed box screening test.

The studies on orientation and settling response of the nymphs indicated that there are distinct differences in the number of nymphs settled on the test cultivars. The orientation and settling response can be considered as a parameter for ascertaining the preference/non preference of the insect. The largest number of nymphs settled were

on the susceptible TN-1 as compared to the other cultivars. Here again the cultivars Cul 126 and Jyothi harboured the lowest number indicating the least preference to these cultivars. The counts taken at one, eight, twenty four and forty eight hours after release did not show variations in the number of insects settled. The results showed that the insects moved to the preferred hosts within one hour and settled for feeding. Gustatory stimuli rather than visual or olfactory stimuli for locating the preferred host has been reported by many workers (Anon, 1971, Pablo 1977). The nymphs probing the seedling using the stylets did not show sustained feeding in the non-preferred hosts and moved away to the preferred hosts. But Khan and Saxena (1985) observed that ovipositional and orientational response were the same in the susceptible and resistant cultivars. However greater preference for settling in susceptible cultivars was reported by many workers (Rodriguez - Rivera, 1972; Pablo, 1977; Khan and Saxena, 1984). Vaidya and Kalode (1981) reported that the nymphs of S. furcifera moved away from the resistant cultures within 2 hours after release.

The pest population dynamics in relation to plant resistance are determined by the rate of reproduction, rate of development, mortality and the length of reproductive life (Dahms, 1969). Population increase can be considered

as an important criterion for assessing the level of resistance in the rice cultivars since it represented the combined effect of all the above factors. (Heinrich and Rapusas, 1983).

There was significant difference in the population build up on the eight cultivars tested. TN-1 supported the highest population in all the counts taken at 10, 20, 30, 40, 50 and 60 days after the introduction of 3 pairs of adults and the highest population was observed at 40 days after introduction. The lowest population was observed in Cul 126 followed by Jyothi. Other cultivars supported population between these extremes. According to a report from IRRI (Anon, 1972), the population of S. furcifera multiplied 10 times more after 30 days and 25 times more after 60 days in susceptible TN-1 as compared to the resistant variety ARC 5752. The lower population in the resistant cultivars was attributed to the adverse effect of the cultivars on the longevity and fecundity of the adults and survival of nymphs. Similar reports were made by several other workers also (Pathak, 1971; Rodriguex - Rivera, 1972; Pablo, 1977; Vaidya and Kalode, 1981). The rate of population growth which could be a reliable parameter in evaluation the degree of resistance, indicated the highest level of resistance in Cul 126, among the test cultivars.

The results of the three preliminary screening trials (seed box screening test, orientation and settling response test and population build up test) were utilised for classifying the test cultivars into resistant, moderately resistant, susceptible and highly susceptible ones. The cultivars Cul 126 and Jyothi which were found to be resistant, Karthika and Pavizham from the moderately resistant group and TN-1 the susceptible check were selected for studying the mechanisms of resistance involved.

Non-preference may be related to oviposition and/or feeding. Both the behavioural patterns generate a complex series of responses to the environmental factors and host characteristics. Ovipositions is often not a fortuitous act. It involves a series of behavioural activities, the initiation and completion of each of which may be influenced by the plant characteristics.

In the experiment on ovipositional preference of adult females it was found that susceptible TN-1 received the highest number of eggs as compared to other cultivars. The lowest number of eggs was deposited on Cul 126 and it was closely followed by Jyothi. The lower number of eggs deposited in the resistant cultivars may be due to plant characteristics which failed to provide appropriate oviposition inducing stimuli or had oviposition inhibitory

stimuli. According to Gunathilagaraj and Chelliah (1985) in the less preferred cultivars chemical differences existed which interfered with the sustained feeding and oviposition of the hopper. Ovipositional preference of S. furcifera was earlier attributed to the chemical stimuli by certain aminoacids (Miyake and Fujiwara, 1961; Miyake, 1966) and high chlorophyll content (Miyake and Fujiwara, 1962). But Rodriguez-Rivera (1972) reported that the preferences for feeding, shelter and oviposition were not always related.

In all the cultivars the leaf sheath received more eggs than the leaf blade. The ovipositional preference of S. furcifera for susceptible TN-1 and its preference for leaf sheath to leaf blade was reported earlier by many workers (Anon 1972; Rodriguez - Rivera, 1972; Pablo, 1977; Vaidya and Kalode, 1981).

Antibiosis signifies those preventive, injurious or destructive effects which the host variety exercises by chemical means on the insects normal life. Death of first instar larva, morphogenic disturbances like decline in size and weight of larva, delayed larval period, reduced fecundity, emergence of short lived adults and behavioural and physiological abnormalities are the pronounced effects of antibiosis (Painter, 1951).

Antibiosis factors of resistance in test cultivars were also observed in the nymphal development in the three stages of plant growth namely seedling, tillering and booting. The shortest duration of nymphal period was observed on TN-1 whereas the maximum was observed on Cul 126. Even in TN-1 the nymphal period showed a slight increase as the age of the plant increased indicating that the earlier stages of plant growth are more suited for nymphal development. This was the case in all test cultivars. The longest developmental period of 18.17 days was found on Cul 126 in the booting stage. Prolongation of nymphal period due to antibiosis effect of host plants has been reported by many workers (Painter, 1958; Jayraj, 1967 ; Natarajan, 1971; Pathak et al., 1971; Sambandam and Chelliah, 1972 ; Rodriguez - Rivera, 1972; Choi, et al., 1973; Pablo, 1977; Vaidya and Kalode, 1981). Prolongation of nymphal period is an important attribute of resistant varieties for it exposes the nymphs to predators for a longer period.

Non preferred cultivars limiting the feeding and the consequent lower survival was also reported earlier (Rodriguez - Rivera 1972; Anon, 1976b; Pablo, 1977). Decrease in the rate of survival with the increase in plant age was also reported earlier (Anon, 1980). When S. furcifera nymphs were caged in three growth stages of the

test cultivars significant differences in the percentage of nymphal survival were noticed. The highest survival percentage was observed in the susceptible TN-1 while the lowest rate was in Cul 126. In all the cultivars it was generally observed that the survival decreased as the age of the plant increased. The adverse effect of resistant cultivars in nymphal survival indicated the operation of antibiosis. Gunathilagaraj and Chelliah (1985) also reported cultivars with certain toxic and deterant substances in them which inhibited the feeding and adversely affected the survival of the insects. The combined effect of non preference and antibiosis might have operated on the insects reared on resistant cultivars.

Inhibitory effects of resistant cultivars on the population build up and in the altered sex ratio of the resulting adults also were observed. The female/male ratio of adult emergents was significantly high in all the growth stage of TN-1 as compared to the other cultivars but no difference in the sex ratio was observed among the three growth stages of the crop. One explanation given to the altered sex ratio in resistant cultivars is the higher mortality of the would be females during the nymphal period. Many workers observed altered sex ratio due to resistance in host plants (Pablo, 1977; Veluswamy, 1982).

Both the females and males reared on TN-1 had longer life span than those reared on the resistant and moderately resistant cultivars. Reduced longevity of adults on resistant cultivars have been reported in N. lugens (Karim Rezaul, 1975; Saxena and Pathak, 1977), in Nephotettix virescense (Cheng, 1969) and in S. furcifera (Gunathilagaraj and Chelliah, 1983). Studies on the longevity of adults reared on the test cultivars revealed that in general the female had more life span than the males. These observations were in agreement with the reports of Choi et al., (1973), Pablo (1977) and Gunathilagaraj and Chelliah (1983). But Rodriguez - Rivera (1972) reported that male plant hopper had longer life span than the female.

Significant differences were observed in the number of eggs laid by insects reared on test cultivars. Insects from susceptible TN-1 produced the maximum number of eggs in the three growth stages as compared to those from the resistant cultivars. This showed that the resistant cultivars were nutritionally deficient or unbalanced and possessed unfavourable biophysical characteristics as compared to susceptible TN-1. Another finding in the studies was that maximum number of eggs were deposited in the tillering stage than in the seeding and booting stages of all test cultivars.

No difference could be observed in the hatching percentage of eggs laid in susceptible and resistant cultivars in the seedling stage. But in the tillering and booting stages, the percentage was higher in TN-1 than in the other cultivars. Adverse effect of resistant cultivars on hatchability of S. furcifera eggs were reported by Rodriguez - Rivera (1972). Saxena and Pathak (1977) recognised egg hatchability as an important factor in the establishment of N. lugens on rice cultivars. Wigglesworth (1972) postulated that water balance and gas exchange are important for the developing embryo inside the egg. The physical and chemical environment of plant tissues in which the eggs are embedded, would influence the egg hatchability. However, Heinrich and Rapusas (1983) did not find any relation between resistance in varieties and hatchability of eggs.

The honey dew excreted had a direct relationship with feeding rate of plant hoppers (Sogawa and Pathak, 1970). Hence a measure of honey dew excreted could be used as a measure of the quantity of food ingested by the insects (Sogawa and Pathak, 1970). According to Patton (1963) the aminoacids, not essential to the nutrition of the insects are normally excreted through the honeydew. The honeydew impregnated areas of the filter paper when treated with ninhydrin would turn to purplish indicating the presence of aminoacids. The area of honeydew spots indicated that the insects fed on TN-1 produced the largest area of

honey dew spots in all the three growth stages namely seedling, tillering and booting as compared to those fed on other test cultivars. The feeding rate was more in the tillering stage than in the seedling and booting stages in all the test cultivars. Auclair and Baldos (1982) reported that the rate of honey dew excretion was 267 times less on the resistant variety. The low rates of honey dew excretion by insects fed on the test cultivars other than TN-1 indicate the low level of ingestion of food due to resistance in the cultivars.

The effect of crowding of first instar nymphs of S. furcifera, at 25, 50 and 100 numbers per plant was highest in the susceptible TN-1 as compared to the resistant ones. The survival percentage was maximum at the crowding of 25 (80.39%) and it decreased at crowdings of 50 (73.27%) and 100 (61.44%). At crowding of 100 the survival rate of nymphs dwindled substantially in the resistant cultivars also. But it is clear from the results that at crowdings at 50 and 100 there is competition for food and space which proved to be detrimental to the optimal rate of population increase.

The results also revealed that the crowding did not affect the sex ratio of emerging adults of S. furcifera reared on test cultivars even though insects from TN-1 had significantly higher female/male ratio as compared to

those from the resistant ones.

Brachypitery among the insects reared on TN-1 was significantly higher than among those from other cultivars. Many explanations have been advanced for alary polymorphism. It has been variously correlated with climate, seasons, mimicry, capability for leaping and rapid locomotion and mode of life whether arborial or otherwise. In the aphidoidea a highly polymorphic group, the development of wings was closely wound up with the wider general problems of morph determination. Genetic control is also implicated in alary polymorphism (Richard and Davies 1977).

Population counts taken 60 days after releasing of S. furcifera and N. lugens in different proportions on the test cultivars gave a clear indication of numerical superiority of N. lugens over S. furcifera. Even when the initial numbers of N. lugens was half that of S. furcifera, the former could surpass the latter in total numbers after 60 days. In the present case both species of plant hoppers compete with each other continuously all through the life cycle. Aspects of interferences include competition for oviposition site, mutual interruption of behavioural pattern, prevention of completion of mating, mortality of eggs and first instar nymphs and competition for food and space.

Hinckley (1963) considered the possibility of inter-specific competition between N. lugens and S. furcifera in Fiji. He concluded that the differences in the dominances of the two species during the crop period were due to the crop age and not of competition. Khan and Saxena (1984) reported that, generally, N. lugens maintained a numerical superiority over S. furcifera and in varieties resistant to N. lugens, S. furcifera multiplied faster. However, according to Gunathilagaraj and Chelliah (1983), it was S. furcifera which maintained a numerical superiority over N. lugens and plant age was attributed as the reason for the same. The results of the present investigation agrees with that of Khan and Saxena (1984).

Information on rice land weeds which serve as alternate host for S. furcifera is vital in formulating management measures against the pest. Out of six species of weed plants tested, the species Cynadon dactylon, Brachiaria sp, Fimbrystylis miliaceae and Cyperus irea were found not suitable for the development of the insect. The other two weeds Echinochloa colona and Panicum repens were found to support the insects. However in Panicum repens, only the males could complete the development. Thus, the species, Echinochloa colona is found capable of supporting a nucleus population of the insect during off seasons.

SUMMARY

SUMMARY

The rice cultivars Cul 126, Cul 93, Ptb 33, Karthika, Pavizham, Triveni and Jyothi with TN-1 as susceptible check were used for preliminary screening for resistance to the whitebacked planthopper, S. furcifera. Seed box screening, free choice and no choice tests and tests on orientation and settling response and population build up were used in the preliminary screening trials.

In the seed box screening, TN-1 recorded the highest damage and the cultivars Cul 126 and Jyothi recorded the lowest damage indicating high susceptibility in the former and high resistance in the latter. The other cultivars Karthika, Pavizham, Cul 93 and Ptb 33 showed moderate levels of resistance. The seed box screening was repeated by free choice and no choice tests and the results were almost similar to those in the seed box screening test.

In the studies on orientation and settling response, the largest number of nymphs settled was on the susceptible TN-1 showing high level of preference. Here again the cultivars Cul 126 and Jyothi harboured the lowest number indicating least preference to the cultivars.

There was significant difference in the population build up of the insect in the cultivars tested. TN-1 supported the highest population in all the counts taken at

10, 20, 30, 40, 50 and 60 days after introduction of 3 pairs of adults. The lowest population was observed on Cul 126 and Jyothi. Other cultivars supported populations between these extremes. The lower population in the resistant cultivars can be attributed to the adverse effect of the cultivars on the survival of the nymphs and the longevity and fecundity of the adults.

The cultivars, Cul 126 and Jyothi (resistant) Karthika and Pavizham (moderately resistant) and TN-1 (highly susceptible) were selected for studying the mechanisms of resistance involved.

In the experiment on ovipositional preference of adult females, it was found that the susceptible TN-1 received the highest number of eggs whereas the lowest number was in Cul 126 and it was closely followed by Jyothi. In all the cultivars the leaf sheath received more eggs than the leaf blade.

The antibiosis factor in the cultivars was investigated in terms of nymphal duration, nymphal survival, sex ratio of emerging adults, adult longevity, fecundity and hatching percentage of eggs in the three growth stages of the crop, namely, seedling, tillering and booting stages.

The shortest nymphal duration was observed on TN-1 in all the three growth stages. The duration was the highest

on Cul 126 which was followed by Jyothi and Karthika. When the three growth stages were compared, the seedling stage was found to be the most suitable and the booting stage the least suitable for nymphal development in all the cultivars. The percentage of nymphs survived to become adults was the highest on TN-1 in all the three growth stages where as it was the lowest on Cul 126. It was generally observed that the survival decreased as the age of the plant increased.

The female/male sex ratio of adult emergents was significantly high in all the growth stages of TN-1 as compared to the other test cultivars, however no difference was observed between growth stages. Both the females and males reared on TN-1 had longer life span than those reared on resistant and moderately resistant cultivars. In general the females had more life span than the males.

Significant differences were observed in the number of eggs laid and the percentage of eggs hatched in different cultivars. Insects from the susceptible TN-1 produced more number of eggs in the three growth stages as compared to those from the resistant cultivars. No differences could be observed in the hatching percentage of eggs laid in the susceptible and resistant cultivars in the seedling stage. However, in the tillering and booting stages the

hatching percentage was higher in eggs on TN-1 than that in the eggs on the other cultivars.

As the honey dew excreted had a direct relationship with the feeding rate, a measure of honey dew excreted could be used as a measure of the quantity of food ingested by the insects. The area of honey dew spots indicated that the insects fed on TN-1 produced the largest area of honey dew spots in all the three growth stages showing a higher feeding rate. The feeding rate was more in the tillering stage than in the seedling and booting stages in all the test cultivars.

The effect of crowding of first instar nymphs of S. furcifera at 25,50 and 100 numbers on the survival percentage of the nymphs was the highest on TN-1 as compared to the resistant cultivars. The survival percentage was maximum (80.39%) at the crowding of 25. The survival of nymphs dwindled substantially in the susceptible and resistant cultivars at the crowding of 100. The results also revealed that different crowdings did not affect the sex ratio of the emerging adults of S. furcifera even though the insects from TN-1 had significantly higher female/male sex ratio as compared to those from the resistance ones. Brachyptery among the insects reared on TN-1 was significantly higher than among those from other cultivars. But crowding at different numbers had no effect on the development of brachypterous insects.

Population counts taken at 60 days after releasing S. furcifera and N. lugens together in different proportions gave a clear indication of the better establishment of N. lugens as compared to S. furcifera. Even when the initial numbers of N. lugens was half that of S. furcifera, the former could surpass the latter in total numbers after 60 days.

In the studies to identify the common wet land weeds which serve as alternate hosts for S. furcifera, it was found that the insects oviposited in none of the weeds studied. When first instar nymphs of the insects were released in the weed plants, the survival was 40 and 20 per cent in Echinochloa colona and Panicum repens respectively. The insect survived in none of the other weeds tested.

The results of the experiments revealed that the cultivars Cul 126 and Jyothi exhibited high level of resistance to the infestation by the white backed plant hopper, S. furcifera and Pavizham and Karthika showed moderate level of resistance.

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* Original not seen.

BIOLOGY AND POPULATION BUILD UP OF THE RICE WHITEBACKED PLANTHOPPER, *Sogatella furcifera* (Horvath) ON DIFFERENT RICE VARIETIES

BY

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ABSTRACT

Investigations were carried out in the College of Agriculture, Vellayani during 1988 to identify cultivars resistant to the white backed planthopper, S. furcifera from among the high yielding rice varieties commonly cultivated in Kerala. The rice cultivars Cul 126, Cul 93, Ptb 33, Karthika, Pavizham, Jyothi, Triveni and TN-1 were chosen for preliminary screening by seed box screening, free-choice and no-choice tests and by tests on orientation and settling response and population build up.

In the seed box screening and free choice and no choice tests, the cultivar Cul 126 recorded the lowest damage and the cultivar TN-1 showed the highest damage, indicating resistance in the former and susceptibility in the latter. The cultivar Jyothi did not differ from Cul 126 and the cultivars Cul 93, Ptb 33, Pavizham and Karthika showed intermediate levels of resistance. In the orientation and settling response test the highest number of S. furcifera nymphs were seen settled on TN-1, where as it was the lowest on Cul 126 and it was followed by Jyothi, indicating a clear preference to the susceptible TN-1. The insect multiplied faster and in greater number on TN-1 and the total count was about thirty times more on TN-1 as compared to that on Cul 126 at 60 days after release.

Based on the results of the preliminary screening trials, the cultivar Cul 126 and Jyothi (resistant), Pavizham and Karthika (moderately resistant) and TN-1 (susceptible check were selected for studying the mechanisms of resistance.

In the experiment to study the ovipositional preference of the insects it was found that the susceptible TN-1 and the resistant Cul 126 received the highest and lowest number of eggs respectively. It was also revealed that the leaf sheath received more eggs than the leaf blade.

The antibiosis factor in the cultivars was investigated in terms of nymphal duration, nymphal survival, sex ratio of emerging adults, adult longevity, fecundity and hatching percentage of eggs in three growth stages of plants, namely, seedling, tillering and booting stages.

The insects from the susceptible TN-1 had the shortest nymphal duration and the longest adult longevity. The percentage of nymphal survival, fecundity and female/male ratio of the emerging adults were also the highest on TN-1. However, the insects from Cul 126, and Jyothi had longer nymphal duration and shorter adult longevity. The survival, fecundity and female/male ratio of the emerging adults from these cultivars were also lower as compared to TN-1. The results were uniform in all the three growth stages of the crop. No difference could be observed in the hatching percentage of eggs in the test cultivars in the seedling stage, but in the tillering and booting stages the eggs on TN-1 showed higher hatching percentage.

The results indicated the presence of antibiosis factor in the resistant cultivars, Cul 126 and Jyothi. These results were further confirmed in the experiment on the feeding rate

of the insect on the test cultivars. Insects on TN-1 produced the largest area of honey dew spots as compared to others in all the three growth stages showing significantly higher feeding rate. The feeding rate in Cul 126 was the lowest.

The effect of crowding of first instar nymphs was more pronounced on the insects on TN-1. The survival percentage was the maximum in crowding at the rate of 25 and it dwindled substantially in the susceptible and resistant cultivars alike in crowding at the rate of 100. Crowding did not have any effect on the sex ratio and brachyptery of emerging adults.

When S. furcifera and N. lugens were released together in different proportions, the latter surpassed the former in total number in all the cultivars when counts were taken at 60 days after release of the insects. The result indicated that in cultivars resistant or susceptible to both the insects, N. lugens established a numerical superiority over S. furcifera.

In studies to identify the wet land weeds which serve as alternate hosts to S. furcifera, it was found that the insects oviposited in none of the weed plants tested. The nymphs could survive only on Echinochloa colona and Panicum repens.