LEAFHOPPER AND PLANTHOPPER PESTS OF RICE IN INDIA

M.B. KALODE,

All India Coordinated Rice Improvement Project, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India.

ABSTRACT

Following the major breakthrough in rice production technology in the later half of the sixties, leafhoppers and planthoppers attained a major pest status during the seventies. The commonly occurring auchenorrhynchan rice fauna from India includes Nilaparvata lugens, Sogatella furcifera, Nephotettix virescens, N. nigropictus, Recilia dorsalis, Cofana (Cicadella) spectra, C. unimaculata (Kolla mimica), Nisia atrovenosa besides the recently reported Empoascanara indica, Unkanodes sapporonus and Laodelphax striatellus. Light-trap catches from various locations in India revealed a wide distribution of the common species and increase in their abundance. Extensive damage by N. lugens leading to 'hopper burn' has been noted in several states from 1973 onwards, while damage by S. furcifera was noted during 1977-1978 in the states of Uttar Pradesh and Punjab.

Besides the direct damage caused through plant sap sucking, some of the hoppers are also known to transmit virus diseases, viz. rice tungro, rice dwarf and yellow dwarf (by Nephotettix spp. and R. dorsalis); ragged stunt and grassy stunt (by N. lugens). Epidemics of rice tungro resulting in heavy yield losses were recorded in Uttar Pradesh and Bihar during 1969 and in Tamil Nadu in 1977. Factors affecting the population build-up of N. lugens are the adoption of nitrogen-responsive, high-tillering dwarf varieties, high plant density and the excessive use of nitrogenous fertiliser that culminate in a dense foliar canopy and multiple cropping.

Emphasis of late has been to control these pests through an integrated pest management strategy involving resistant varieties followed by need-based insecticidal control. An intensive screening programme led to the identification of several donors including Ptb 2, ADT 21, Ptb 7 and Ptb 18 against Nephotettix spp.; Ptb 33, Monoharsali and Sinna Sivappu against N. lugens, besides Velutha Cheera, Bellai Langayan with multiple resistance. The utilization of some of these has resulted in the development of cultures with resistance and high yield potential. Some of the important cultures are IET 7302, IET 7303 against green leafhoppers and tungro virus; IET 6315, IET 7575, IET 6314, IET 5683 against N. lugens and IET 6288 against S. furcifera. The occurrence of biotypes capable of overcoming varietal resistance is noted in some instances. Recent multilocation

coordinated research under the AICRIP programme, however, indicated no biotypic differences in N. lugens populations within the country. The conservation of predators such as the mirid bug Cyrthorhinus lividipennis needs consideration in integrated pest management programmes for this pest.

INTRODUCTION

Out of 145 million hectares grown to rice in the world, 129 million hectares occur in Asia. In area, India occupies the first position in the world (40.5 million ha) with an annual production of 83 million tonnes of paddy. However, despite efforts to increase production, the average yield has remained relatively low (2.1 t/ha) in the country, due to various factors. Among these, insect pests are one of the major constraints as evident from the multilocation trials conducted under an AICRIP programme involving 135 experiments (1969-1977). Employing identical varieties, protected crops yielded 28.8% more on average than the unprotected ones. There have also been instances where an individual pest or pest-complex was responsible for total failure of the crop in endemic areas.

With intensive management practices, some of the pests which were hitherto considered to be of minor importance assumed increased pest status in several areas. Amongst the leafhopper and planthopper pests, the brown planthopper, the green leafhopper and the white backed planthopper are some of the examples of the above situation. The work done in the Indian subcontinent on these pests is briefly reviewed.

COMMON SPECIES AND THEIR DISTRIBUTION

The most common auchenorrhynchous species on rice in India are the green leafhoppers (GLH), Nephotettix virescens (Distant), N. nigropictus (Stål); zigzag leafhopper, Recilia dorsalis (Motsch.); white leafhoppers, Cofana (= Tettigella) spectra (Distant), C. unimaculata (Signoret) (= Kolla mimica Distant); brown planthopper (BPH), Nilaparvata lugens (Stal); white backed planthopper (WBPH), Sogatella furcifera (Horvath); and white winged planthopper, Nisia atrovenosa Lethierry. These species are widely distributed in the country and have been recorded from all the rice-growing states. Other species recorded are Unkanodes sapporonus (Matsumura) from Orissa (Misra 1975), Empoascanara indica (Datta) from Karnataka (Manjunath and Urs 1979), the smaller brown planthopper, Laodelphax striatellus (Fallén) from Punjab (Shukla 1979), and Indoformosa indica (Datta) from Andhra Pradesh (Kalode unpublished). The distribution of these species is not known since no systematic survey has been done. Besides the above species, the sugar-cane leafhopper, Pyrilla perpusilla (Wlk.) has been reported on rice in Uttar Pradesh (Sukhani 1971, Pawar 1981). However, no study seems to have been done on the suitability of rice as the host of this species.

RELATIVE PEST STATUS

There has been an increasing trend in relative abundance of leafhoppers and planthoppers during recent years (Kalode and Viswanathan 1976). Light-trap catches from several locations, viz. at Maruteru, Warangal, Rajendranagar (Andhra Pradesh) and Pattambi (Kerala) have indicated further increases in monthly catches. Nephotettix spp. have increased 1.6 to 4.4 times during 1976-78 and 1.6 to 5 times during 1979-81 (Table 1). Likewise, brown planthopper catches at Maruteru increased 3.1 times during 1976-81 compared to those during 1972.

TABLE 1.

Light-trap catches of green leafhoppers Nephotettix spp. and brown planthopper Nilaparvata lugens at different locations in India

Location	Average numbers caught per month during			Times increase over 1972 during	
	1972	1976-78	1979-81	1976-78	1979-81
		Nephotettix spp.			
Maruteru	19,265	33,659	81,371	1.75	4.22
Warangal	16,626	49,667	26,684	2.99	1.61
Rajendranagar	2,061	9,260	10,425	4.49	5.06
Pattambi	2,781	4,517	4,332	1.63	1.56
		Nilaparvata lugens			
Maruteru	33,247	1,03,304	1,04,415	3.11	3.14

AICRIP Reports from 1972 to 1981

Though there has been an appreciable increase in the populations of leafhoppers and planthoppers during the seventies, records of outbreaks are available even in earlier years. Major pest status of the white backed planthopper (S. furcifera) has been noted since 1962 in Madhya Pradesh (Patel and Tiwari 1967), while serious damage by the pest was noted in Punjab during 1966 and 1967 (Choudhary and Ramzan 1968) and also subsequently during 1972, 1975 and 1978 (Sidhu 1979). Outbreaks of this hopper on upland rice in northern parts of West Bengal were observed during 1969 (Chatterjee 1971), and during 1977 in Uttar Pradesh (Verma et al. 1979a). Extensive damage leading to "hopper burn" by the brown planthopper (N. lugens) was noted in Kerala during 1973-74 and 1976 (Kulshreshtha et al. 1974, Nalinakumari and Mammen 1975, Kalode and Viswanathan 1976, Anonymous 1976a); in Karnataka and West Bengal during 1975 (Channabasavanna et al. 1976, Nath and Sen 1978); in Andhra Pradesh, Madhya Pradesh and Orissa in 1976 (Prakasa Rao et al. 1976, Anonymous 1976b) and in Tamil Nadu and Pondicherry during 1977 (Natarajan and Palchamy 1978, Rajendrana and Narayanasamy 1978).

Outbreaks of brown planthopper in Bangladesh in 1976 and in Sri Lanka in 1974 are reported (Alam and Karim 1976, Abeyrante 1976), while those of white backed planthopper in Bangladesh during 1963, 1967 and 1977 (Alam and Alam 1977) and in Pakistan during 1953 itself (Ghauri 1979) are also recorded.

ROLE AS VECTORS OF VIRUS DISEASES

Besides the direct damage caused by plant feeding, transmission of virus diseases by leafhoppers and planthoppers is well known. Though as many as 11 virus diseases of rice are reported to be associated with hoppers (Singh 1971, Heinrichs 1979), not all have been reported from India. Rice tungro virus (RTV) disease has been reported from the states of Andhra Pradesh, Bihar, West Bengal, Orissa, Tripura, Assam, Manipur, Kerala and Tamil Nadu (Reddy 1973, Anjaneyulu and Chakrabarti 1977, Kannaiyan *et al*. 1978). The existence of RTV in India was obscure until 1969 when an epidemic was noted in Uttar Pradesh. Though RTV is generally associated with *N. virescens*, it is reported to have been spread by *N. nigropictus* in Manipur during 1973 and in Kerala in 1974 (Anjaneyulu and Chakrabarti 1977). Yellow dwarf disease, also transmitted by these species has been reported from West Bengal, Orissa, Tamil Nadu, Karnataka and Kerala. Another important virus disease, ragged stunt, transmitted by BPH (*N. lugens*) was first noted in 1975 in Orissa (Ghosh *et al*. 1979) and was subsequently reported from Tamil Nadu, West Bengal and Pondicherry (Heinrichs and Khush 1978, Naik 1979). Grassy stunt, also transmitted by BPH, is reported from Kerala. However, the spread of these latter two diseases is not significant in India. RTV is also reported from countries like Bangladesh, Sri Lanka and Nepal; yellow dwarf is reported from Bangladesh while ragged stunt and grassy stunt are known to occur also in Sri Lanka.

In Punjab, although green leafhoppers - mainly *N. nigropictus* - are abundant, no virus disease transmission is known (Dhawan and Sajjan 1976). Likewise, although the vectors *L. striatellus* and *U. sapporonus* are reported, the virus diseases stripe and black-streaked dwarf have not been noticed.

FACTORS FAVOURING BUILD-UP

The phenomenal outbursts in populations of planthoppers - particularly BPH - in recent years have led investigators to probe into the factors responsible for these. Inferences have been drawn mainly from circumstantial evidence and partly from experimentation. The planthopper problem has arisen subsequent to the widespread adoption of intensive management practices involving cultivation of nitrogen-responsive, high-tillering dwarf varieties with excessive use of nitrogenous fertilisers and continuous cropping. Multilocation trials under AICRIP programme (Anonymous 1979) have demonstrated a higher planthopper population in a closely planted (10 x 10 cm) crop compared to one with wider spacings (15 x 20 or 30 x 30) (Table 2).

TABLE 2.

Effect of plant spacing on population density of the brown planthopper, Nilaparvata lugens

Plant spacing	Number of hoppers per 100 tillers
10 x 10 cm	73.6
15 x 20 cm	30.0
30 x 30 cm	43.2

AICRIP Reports for 1978 and 1979

Likewise, closer spacing leading to dense canopy resulted in significantly higher BPH population per unit area (Pillai et al. 1979, Venkateswarlu and Kalode 1981). However, experiments conducted elsewhere indicated that the number of nymphs per tiller remained relatively constant over various spacings and that higher tiller density per unit area, achieved through either closer spacing or higher number of tillers per hill, favoured higher population (Duck et al. 1979). Several authors reporting BPH outbreaks have suggested excessive use of fertilisers as one of the possible causes (Israel and Prakasa Rao 1968, Banerjee et al. 1973, Abraham and Nair 1975, Velusamy et al. 1975, Kalode 1976). It has also been demonstrated experimentally in the field that planthoppers were abundant on plants treated with large amounts of nitrogen or nitrogen and phosphorus (Abraham 1957, Pillai et al. 1979). Further, females reared on plants receiving larger amounts of nitrogen showed higher fecundity (Kalode 1971). Thus it is apparent that besides the change in the micro-environment following high fertiliser application, nutritional and physiological aspects of the pest are also responsible for the above-noted effects. Standing water in the field has often been suggested as favouring BPH build-up (Israel 1969, Banerjee et al. 1973) which has been experimentally proved (Duck et al. 1979).

Besides the above factors, the presence of weeds in and around rice fields is looked upon as a source of the pest build-up (Kulshreshtha et al. 1979). Despite several alternate host plants being reported for BPH, it is not certain, however, that weeds play a positive role in population build-up. Similarly, stubbles left over after harvest are also considered to be potential sources of initial infestation of planthoppers (Duck et al. 1979). The extensive area of rice cultivation has been interpreted to favour pest populations (Kulshreshtha et al. 1974, Abraham and Nair 1975). With the availability of short-duration photoinsensitive varieties there has been a tendency to go in for double or multiple cropping of rice per year in areas with assured irrigation. This has been noted as yet another important factor causing outbreaks of BPH (Kalode 1976, Kulshreshtha et al. 1974, Abraham and Nair 1975). There are, however, cases of hopperburn where one crop a

TABLE 2.

Effect of plant spacing on population density of the brown planthopper, Nilaparvata lugens

Plant spacing	Number of hoppers per 100 tillers
10 x 10 cm	73.6
15 x 20 cm	30.0
30 x 30 cm	43.2

AICRIP Reports for 1978 and 1979

Likewise, closer spacing leading to dense canopy resulted in significantly higher BPH population per unit area (Pillai et al. 1979, Venkateswarlu and Kalode 1981). However, experiments conducted elsewhere indicated that the number of nymphs per tiller remained relatively constant over various spacings and that higher tiller density per unit area, achieved through either closer spacing or higher number of tillers per hill, favoured higher population (Duck et al. 1979). Several authors reporting BPH outbreaks have suggested excessive use of fertilisers as one of the possible causes (Israel and Prakasa Rao 1968, Banerjee et al. 1973, Abraham and Nair 1975, Velusamy et al. 1975, Kalode 1976). It has also been demonstrated experimentally in the field that planthoppers were abundant on plants treated with large amounts of nitrogen or nitrogen and phosphorus (Abraham 1957, Pillai et al. 1979). Further, females reared on plants receiving larger amounts of nitrogen showed higher fecundity (Kalode 1971). Thus it is apparent that besides the change in the micro-environment following high fertiliser application, nutritional and physiological aspects of the pest are also responsible for the above-noted effects. Standing water in the field has often been suggested as favouring BPH build-up (Israel 1969, Banerjee et al. 1973) which has been experimentally proved (Duck et al. 1979).

Besides the above factors, the presence of weeds in and around rice fields is looked upon as a source of the pest build-up (Kulshreshtha et al. 1979). Despite several alternate host plants being reported for BPH, it is not certain, however, that weeds play a positive role in population build-up. Similarly, stubbles left over after harvest are also considered to be potential sources of initial infestation of planthoppers (Duck et al. 1979). The extensive area of rice cultivation has been interpreted to favour pest populations (Kulshreshtha et al. 1974, Abraham and Nair 1975). With the availability of short-duration photoinsensitive varieties there has been a tendency to go in for double or multiple cropping of rice per year in areas with assured irrigation. This has been noted as yet another important factor causing outbreaks of BPH (Kalode 1976, Kulshreshtha et al. 1974, Abraham and Nair 1975). There are, however, cases of hopperburn where one crop a

year is grown (Freeman 1976). It has been pointed out that new varieties are intrinsically more susceptible to BPH than the traditional varieties (Pradhan 1971, 1975, Diwakar 1975). But it may not be so since the agronomic practices associated with new varieties lead to the development of distinctly different micro-climates which themselves might facilitate the planthopper build-up (Shastry 1971, Freeman 1976, Pathak and Dhaliwal 1981). The dense canopy formed by the broader-leaved variety RP 143-4 harboured higher numbers of planthoppers than the narrow-leaved Sona (Venkateswarlu and Kalode 1981).

BIOLOGY AND HOST RANGE

Biological studies have been made by several workers under varying environmental conditions on Nephotettix spp. (Misra and Israel 1968, 1970, Dhawan and Sajjan 1976, Viswanathan 1977) and Nilaparvata lugens (Venkata Swamy 1976), S. furcifera (Vaidya and Kalode 1981). Many of these studies have also noted the host range of the species by offering most of the common weed species found in and around rice fields. Misra and Israel (1970) noted Echinocloa colonum, Leersia hexandra for N. virescens, and E. colonum, L. hexandra and Saccharum officinarum for N. nigropictus to be suitable hosts for feeding and reproduction. Besides E. colonum, other weeds like Paspalam distichum, Cyperus rotundus and Cynodon dactylon were also reported as alternate host plants of tungro virus and its vector N. virescens (Prasad Rao and John 1973). From Bangladesh, Alam (1974) identified L. hexandra as the principal host of N. virescens and also observed hopperburn in that weed.

In a detailed study carried out at AICRIP, various criteria were used by Viswanathan (1977) while testing 54 different plant species against both species of Nephotettix. It was concluded that none of the test plants was suitable for N. virescens' survival except rice, whereas N. nigropictus had a wider host range with L. hexandra being the principal host followed by E. colonum, rice and E. crus-galli. The latter species could also survive and breed to a limited extent on C. dactylon, Oryza officinalis, Panicum repens and S. officinarum (Table 3).

In similar studies on N. lugens 39 species of plants were tested for insect survival (Venkata Swamy and Kalode 1979). Besides rice, only Cyperus difformis and E. colonum could support nymphal development for up to 24 days. Vaidya (1978) investigated the suitability of 20 plant species for WBPH (S. furcifera) and noted that the species could survive and breed on Chloris barbata as well as rice, while a proportion of nymphs survived to become adults on E. colonum, P. geminatum, L. hexandra and Panicum sp.. There is apparent contradiction in the foregoing records as regards the status of certain plant species as alternate hosts of leafhoppers and planthoppers. Geographical variation in the ability of the insect to adapt to different plant species is likely to be expected as illustrated in the case of the rice gall midge, Orseolia oryzae (Kalode 1980).

TABLE 3.

Survival, adult longevity and fecundity of Nephotettix nigropictus on various plant species

Plant species	% survival after 21 days of release	Av. adult longevity (days) Female	Male	Fecundity (*)	Growth index
Leersia hexandra	65	21.2	19.5	223.0	3.77
Echinochloa colonum	52	19.5	19.0	159.5	2.81
Oryza sativa (Rice)	50	20.5	19.0	174.0	2.80
E. crus-galli	48	21.0	17.5	189.0	2.17
Saccharum officinarum	21	12.5	10.5	13.0	1.15
Cynodon dactylon	6	10.5	11.0	21.0	0.28
O. officinalis	6	10.0	9.5	16.0	0.27
Panicum repens	4	7.0	9.0	38.0	0.19

(*) Average number of eggs laid per female.

Viswanathan 1977

VARIETAL RESISTANCE

Greater emphasis is given in the country to develop varieties resistant to leafhoppers and planthoppers. Several research centres including AICRIP at Hyderabad, Central Rice Research Institute at Cuttack, Tamil Nadu Agricultural University at Coimbatore, G.B. Pant University of Agriculture & Technology, Pantnagar and Research Stations at Pattambi, Maruteru and Aduthurai in India are actively engaged in this work. Progress made towards this objective up to 1976 has been reviewed by Kalode and Krishna (1979) while the more recent work of AICRIP is covered by Kalode et al. (1980). The main emphasis is on the brown planthopper; a total of 30,000 germplasm accessions and breeding materials have been evaluated against this pest under glasshouse conditions adopting a mass screening technique (Kalode et al. 1975). As a result, about 250 donors have been identified of which more than half of the entries are from Assam Rice Collections originating from Eastern India (ARC 5500, ARC 5754, ARC 5757, ARC 5764, ARC 5780, ARC 5838, ARC 5917, ARC 5973, ARC 5981, ARC 5988, ARC 12864, ARC 13854, ARC 13966, ARC 14394, ARC 13507, ARC 14539, ARC 14766-A, ARC 14703, etc.).

Some of the important donors that have been used in a breeding programme include Ptb 33, Ptb 21, Leb Mue Nahng, Manoharsali,

CR 57-MR 1523 and ARC 6650. One of the tolerant cultures developed (IET 6314) from cross RP 31-49-2 x Leb Mue Nahng has been released in Tamil Nadu state for cultivation as Co 42. However, more promising cultures generated from cross Sona x Manoharsali are in the pre-release stage (Table 4).

TABLE 4.

Important donors being utilised in breeding programme for resistance against leafhoppers and planthoppers

Insect	Donor	Cross	Promising progenies
Brown planthopper	Manoharsali	Sona x Manoharsali	IET 6315 IET 7568 IET 7571 IET 7575
	Leb Mue Nahng	RP 31-49-2 x Leb Mue Nahng	IET 6314
	Ptb 21	Vijaya x Ptb 21	IET 5688
	ARC 6650	RPW 6-17 x ARC 6650	RP 1579-2256
Green leafhoppers	Ptb 2	RPW 6-13 x Ptb 2	IET 7301 IET 7302 IET 7303
	ADT 21	Rasi x ADT 21	IET 7562 IET 7563
White backed planthopper	IET 6288	IET 6288 x Phalguna	RP 2149 selections

Recent glasshouse screening results at Cuttack identified 6 resistant ARC accessions (ARC 13506, ARC 13530, ARC 13536, ARC 13556, ARC 13872, ARC 13909) as well as AC 3747 and AC 3376 out of 510 entries tested (Anonymous 1977, 1978). An artificial infestation method in the glasshouse identified 22 entries as promising out of 988 tested at Coimbatore (Balasubramanian *et al.* 1978). Of these Nira - a variety from the USA - was reported to be most promising. Field screening at Aduthurai identified resistant entries in terms of the number of insects per hill (Natarajan and Chandy 1980). Since such field screening, entirely dependent on natural infestation, often led to variable reactions, an improved method of field screening with techniques to ensure high and uniform insect populations was recently developed and resistant reactions of the cultures developed have been confirmed (Kalode *et al.* 1982).

A total of 108 rice varieties were evaluated against Nephotettix spp. at AICRIP, adopting the mass-screening method, nymphal survival and adult survival tests. The ten varieties Ptb 2, Ptb 18, Ptb 7, Khamma 4918, Ptb 21, DS 1, ARC 6049, Khamma 4912, ARC 10243 and Jhingasail exhibited high levels of resistance to both species (Viswanathan 1977). Recent screening tests have shown several entries resistant to rice tungro virus, ragged stunt and grassy stunt virus diseases (Seetharaman and John 1981). In the breeding programme, Ptb 2 and ADT 21 have been utilised as resistant donors, and cultures IET 7301, IET 7302, and IET 7303 have shown promise in resistance and yield (Table 4). Field screening of 980 varieties at Sambalpur in Orissa identified 29 entries resistant to tungro virus (Naik and Misra 1977) while similar evaluation against leafhopper and stem borer at Cuttack outlined 7 entries with combined resistance including TG 37 from Indonesia (Prakasa Rao 1977).

Screening varieties against S. furcifera initiated recently at AICRIP is focussed on identifying varieties resistant to both BPH and WBPH and 40 such cultivars were noted for their resistance (Kalode et al. 1977). Vaidya and Kalode (1981) screened 536 varieties-cultures and identified 10 entries as resistant. Donors involved in a breeding programme against this pest are IET 6288, Ptb 33 and Velluthacheera. Glasshouse screening against this pest has also been initiated at Ludhiana in Punjab and Coimbatore in Tamil Nadu, while field screening is carried out at Kapurthala in Punjab.

The status of varietal resistance against BPH in Sri Lanka has been reviewed by Fernando et al. (1979). Glasshouse screening of 450 entries in Bangladesh identified 10 highly resistant entries including donors like ARC 6650, ARC 10550, ARC 14529, Sinna Sivappu and Hondarawala (Kabir and Alam 1981).

MECHANISM OF RESISTANCE

Studies on the nature of resistance in the varieties against leafhoppers and planthoppers highlighted predominantly 'antibiosis' and 'nonpreference' mechanisms. Low numbers of nymphs of the brown planthopper settled on five of the test varieties viz., Ptb 33, Ptb 21, Leb Mue Nahng, ARC 6650 and CR 57-MR 1523 as compared to that on susceptible T(N)1 (Kalode et al. 1978). Further, nymphal survival and population build-up were also adversely affected to varying degrees on these varieties. A honeydew test revealed restricted feeding on some of the above test varieties while on Leb Mue Nahng and T(N)1 insects excreted profusely, indicating a higher level of plant sap ingestion (Kalode and Krishna 1979). However, CR 57-MR 1523 studied at all growth stages showed a high degree of tolerance even under high insect population pressure (Kalode et al. 1978). In another detailed study at AICRIP by Reddy (1979), resistant ARC accessions like ARC 5780 and ARC 5988 showed high degrees of nonpreference and antibiosis mechanism. Nymphal development on resistant varieties was prolonged by 3-7 days. These varieties bore higher numbers of probing marks made by the insects in their attempts to feed. Further, planthoppers confined on test varieties for 6 hours lost 9-40% of their body weight compared

to those on susceptible checks which gained 27% in weight (Table 5).

TABLE 5.

Change in body weights of adults of brown planthopper, Nilaparvata lugens, when confined to rice varieties for six hours

Variety	Reaction against BPH (*)	Net gain (+) or loss (-) in body weight (mg)	% loss or gain in body weight
Experiment 1			
ARC 5924	MR	- 1.9	- 12.67
ARC 5906	MR	- 1.8	- 12.86
ARC 5834	R	- 4.0	- 26.67
ARC 5780	R	- 5.0	- 33.33
Ptb 33	R(check)	- 4.4	- 31.43
T(N)1	S(check)	+ 2.9	+ 27.62
Experiment 2			
Ptb 21	MR	- 1.2	- 9.23
ARC 14426	MR	- 2.6	- 17.34
ARC 13507	R	- 3.9	- 30.00
ARC 13854	R	- 4.2	- 30.00
ARC 14766-A	R	- 5.0	- 39.45
Ptb 33	R(check)	- 4.1	- 29.29
T(N)1	S(check)	+ 3.6	+ 27.70

(*) MR = moderately resistant
R = resistant
S = susceptible

Reddy 1979 (modified)

The amount of honeydew excreted was 6.6 to 11.9 times less on resistant entries vis-à-vis the susceptible check. These manifestations of antibiosis indicate that the variety is acceptable to the insect in terms of nutritional quality and quantity. Prolonged nymphal development was noted on Ptb 33 and MR 1523 in studies carried out at Cuttack (Anonymous, 1978). It was also noted in biochemical analysis studies that there were high levels of amino-acids and phenolic compounds in resistant varieties, while soluble sugar levels were high in susceptible varieties.

The pattern of resistance in three highly resistant entries, Ptb 2, Ptb 18 and Ptb 7, was investigated in the case of Nephotettix spp. (Viswanathan 1977). The insects did not prefer the varieties for settling or egg laying but made more punctures in attempts to feed on them. However, histological observations did not indicate any mechanical barrier obstructing feeding. 'Antibiosis' exhibited by the entries was of a high order and independent of plant age. A biochemical approach indicated a higher content of total phenols and lower levels of free amino-acids in resistant varieties than in the susceptible check. These results, however, could not be linked to resistance, as the weed L. hexandra also showed higher phenol content and lower amino-acids despite being the preferred host of N. nigropictus. Bioassay studies revealed sucrose and some amino-acids to be feeding stimulants while amino acid derivatives, organic acids and phenols were strong deterrents. Likewise, chloroform and acetone extracts of resistant varieties were preferred less by both species in contrast to similar preparations of susceptible checks. It was concluded from the above studies that resistance to green leafhoppers tends to be biochemical in nature, primarily in the form of the presence of phago-deterrents and/or the absence of certain phagostimulants (Viswanathan 1977). Antibiosis in the resistant variety 'Latisail' with regard to both N. virescens and N. nigropictus was noted in terms of reduced oviposition and adult longevity, and prolonged egg incubation period and nymphal instars (Dutt and Biswas 1979).

Selecting 12 resistant varieties based on mass screening tests, Vaidya and Kalode (1981) noted the nature of resistance against S. furcifera. Distinct non-preference was noted in nymphal and adult settling and oviposition with respect to varieties IET 6288, ARC 11208, A 1 and IR 781-144-1-IR 8/2, whilst ARC 5955 and ARC 11351 had high antibiosis resulting in reduced nymphal survival and population build-up in the second generation.

BIOTYPIC VARIATIONS

One of the major problems limiting the extensive use of resistant varieties against leafhoppers and planthoppers is the presence or development of biotypes in pest populations capable of overcoming the resistance. This is well documented in the case of the brown planthopper. The resistant variety IR 26 developed at IRRI, Philippines, when tested in Kerala and at AICRIP, India, in 1975, was found to be totally damaged. This has given the first indication of the possibility of biotypes in this insect. Later through the International Rice Testing Programme (IRTP) it was confirmed that the biotype of south Asia was entirely different from those found in the rest of the BPH-occurring regions (Seshu and Kauffman 1980). Even within the latter region new biotypes have been found to be developing in countries like the Philippines, Indonesia, Korea and Japan following extensive cultivation of resistant varieties (Heinrichs 1979). The reactions noted against Ptb 33 and related entries in IRTP at Pantnagar led to belief in the existence of a different biotype in Northern India -

particularly at Pantnagar - as against the one in South India (Pathak and Lal 1976, Pathak et al. 1978, Verma et al. 1979b, Pathak and Verma 1980). Since all the test entries at this location have been reported to be susceptible and no single entry had shown resistance, it has not been possible to characterise this biotype. However, recent AICRIP data (Anonymous, 1981) and personal observations made by the author did not reveal differential reactions, and hence the presence of more than one biotype of BPH within India is doubtful. Though reactions noted against BPH in Sri Lanka and India are similar, in Bangladesh variable reactions against Ptb 33 are noted (Kabir and Alam, 1981). Preliminary observations on green leafhoppers and white backed planthopper indicated similar types of variation in response to resistant varieties to those observed in different countries. Further detailed studies are needed to confirm the probable existence of biotypes among these hoppers. In view of the documented rapid development of biotypes in BPH populations elsewhere, constant surveillance is necessary to detect them in fields of different regions.

NATURAL ENEMIES

Attempts towards biological control of leafhoppers and planthoppers are limited mainly to surveys of natural enemies and studies of their biology and biocontrol potential. The most common parasitoids recorded are egg parasites, Anagrus spp., Oligosita spp., Gonatocerus sp., Paracentrobia andoi; and nymphal and adult parasites belonging to the families Dryinidae (Gonatopus, Haplogonatopus, Pachygonatopus, Echthrodelphax), Elenchidae (Elenchus), Pipunculidae (Tomosvaryella, Pipunculus) and Mermithidae (Nematoda; Hexamermis) (Choudhary and Ramzan 1968, Munjunath, 1978, Manjunath et al. 1978, Samal and Misra 1978). A large number of predators are also recorded. The biology and control potential have been noted for the coccinellid Harmonia arcuata (Israel and Prakasa Rao 1968), the mirid Cyrtorhinus lividipennis (Samal and Misra 1977a, Pophaly et al. 1978), the spider Marpisa pomatix (Samal and Misra 1977b), egg and nymphal parasites (Samal and Misra 1978, Bentur et al. 1982) and the predatory water strider Limnogonus nitidus (Samal and Misra 1982). Two species of fungus, viz. Entomophthora fumosa and Beauveria bassiana have also been noted to infect BPH (Samal et al. 1978, Srivastava and Nayak 1978).

The role of natural enemies, particularly C. lividipennis, in the population build-up of BPH has been demonstrated in field trials through elimination by repeated insecticide sprays (Bentur and Kalode 1980). In unsprayed plots the hoppers multiplied an average of 15.4 times in 40 days whereas in plots regularly sprayed to eliminate mirid bugs they multiplied 26.9 times.

CHEMICAL CONTROL

Work on the chemical control of leafhoppers and planthoppers includes screening of insecticides to identify those with faster knockdown and longer persistence. Venkata Swamy and Kalode (1981) tested 62 insecticides against BPH and noted Mipcin and carbofuran granules

and carbaryl and monocrotophos sprays to possess immediate knock-down effects. However, Mipcin, turbofos, disulfoton and carbofuran as granules and ethyl parathion, San 155 (SP) and Sevimol as sprays registered longer persistence (6 to 25 days). Field studies showed relatively better effectiveness of carbofuran and phorate as granules while methamidophos and Phoxim were better as sprays against BPH (Narayanaswamy and Balasubramanian 1977). Carbofuran was also reported to be effective against tungro virus through control of the vectors (Rao et al. 1977). In further studies at AICRIP 14 new insecticides were tested against BPH revealing that fenvalerate, cypermethrin and carbosulfan had better knock-down effect both under a Potter's tower and when sprayed on the plants (Krishnaiah, Kalode and Sarma unpublished). Since sprays are often directed at the foliar canopy as practised by farmers, the downward translocation (from leaf to stem) of 9 insecticides was investigated. Only BPMC showed such a property, but its effectiveness did not last longer than 5 days. The above study also identified the ovicidal activity of carbosulfan, MIPC, BPMC, knockbal, carbaryl, isofenphos, phosalone and monocrotophos out of 18 spray formulations tested. Another set of experiments (Krishnaiah and Kalode 1980) revealed knock-down effects of FMC 35001 and BPMC when sprayed on plants and of FMC 35001 under a Potter's tower. Of the 33 spray formulations evaluated against WBPH, 16 of them, including fenvalerate, FMC 35001, cypermethrin and fenitrothion were effective. Against Nephotettix sp., San 155, Mipcin and BPMC granules showed immediate knock-down effect, while San 155 exhibited greater persistence (15 days).

In order to reduce the cost of insecticide application in the field, the seedling root-dip technique has been developed. Eight insecticides against green leafhoppers and 19 against BPH were tested as seedling root-dip treatments. San 155 at 0.04 per cent and carbosulfan at 0.02% were effective against green leafhoppers while carbofulfan also showed ovicidal activity against brown planthopper (Krishnaiah and Kalode unpublished).

In a study to note the knock-down speed of insecticides, Misra and Shanker (1980) noted least LT 50 values against BPMC of 0.05% and against BPMC + carbaryl (1 : 1) of 0.05% with reference to green leafhoppers and brown planthoppers. Out of 6 insecticides tested for relative toxicity against brown planthopper and its predator Cyrtorhinus lividipennis, fenthion gave least kill of the predator (20%) while being effective against the hopper (Krishnadoss and Abdul Kareem 1980). Rao and Prasaka Rao (1980a) recorded that placement of carbofuran in capsules at depths of 1.25, 2.5, 3.75 and 5 cm below the soil-surface did not affect its efficacy in pot culture studies. As based on LD 50 values the performance of chemicals was of the following order - phosphamidon (0.0034%), monocrotophos (0.00404%), carbofuran (0.0052%) and chlorpyrifos (0.0055%) (Rao and Prakasa Rao 1980b). In their attempts to note the efficacy of granular insecticides on different developmental stages of brown planthopper, Koshiya et al. (1981) tested 9 insecticides at 1 kg a.i./ha rate. AC 64475, carbofuran and phorate were effective against different instars. In view of several

reports of resurgence in planthopper populations following insecticide applications, field experiments were conducted at AICRIP. It was noted during one season that monocrotophos at a sub-lethal concentration of 0.02% and methyl parathion at 0.02 and 0.05% resulted in higher planthopper populations when observed 93 days after transplanting (Krishnaiah and Kalode unpublished).

Efforts have also been made to demonstrate the role of different control methods in pest management systems against brown planthopper in AICRIP trials. At Maruteru, a BPH endemic location, the hopper-resistant variety IET 6315 registered a lower pest population (25 individuals per hill) and gave relatively higher yield (2.5 t/ha) under unprotected conditions as against the check variety Jaya (119 individuals/hill and 1.3 t/ha). With need-based protection against other pests, the potential yield of 5 to 6 t/ha was realised with the former variety (Anonymous, 1981). Thus conservation of natural enemies through need-based use of insecticides, adoption of cultural practices like wider spacings (20 x 15 cm), judicious application of nitrogenous fertilizers coupled with cultivation of resistant varieties, need consideration in integrated pest management programmes against leafhopper and planthopper pests of rice.

ACKNOWLEDGEMENTS

I am thankful to Dr. R. Seetharaman, Project Director, All India Coordinated Rice Improvement Project, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India, for his keen interest in this work and for going through the manuscript.

REFERENCES

Abeyrante, A.M. (1976) Brown planthopper damage in Sri Lanka. Int. Rice Res. Newslett. 1(2), 8.

Abraham, C.C.; Nair, M.R.G.K. (1975) The brown planthopper outbreaks in Kerala, India. Rice Entomol. Newslett. 2, 36.

Abraham, E.V. (1957) A note on influence of manuring on the incidence of the fulgorid Nilaparvata lugens Stål on paddy. Madras Agric. J. 44, 529-532.

Alam, S. (1974) Recent ecological studies in rice insects - leafhoppers and planthoppers. Int. Rice Res. Conf. Philippines (Mimeo), 3p.

Alam, S.; Karim, A.N.M.R. (1976) Brown planthopper outbreak in Bangladesh. Int. Rice Res. Newslett. 1(2), 8.

Alam, S.; Alam, M.B. (1977) White backed planthopper outbreak in Bangladesh. Int. Rice Res. Newslett. 2(5), 19.

Anjaneyulu, A.; Chakrabarti, N.K. (1977) Geographic distribution of tungro virus disease and its vectors in India. Int. Rice Res. Newslett. 2(5), 15-16.

Anonymous (1976a) Outbreaks of pests and diseases. Quart. Newslett. FAO Plant Protection Committee for the Southeast Asia and Pacific Region, 19(2), 3-5.

Anonymous (1976b) Outbreaks of pests and diseases. Quart. Newslett. FAO Plant Protection Committee for the Southeast Asia and Pacific Region, 19(4), 3-4.

Anonymous (1977) Annual Report, Central Rice Research Institute, Cuttack. Indian Council of Agricultural Research, New Delhi, 269pp.

Anonymous (1978) Annual Report, Central Rice Research Institute, Cuttack. Indian Council of Agricultural Research, New Delhi, 336pp.

Anonymous (1979) Kharif Report, All India Coordinated Rice Improvement Project, Hyderabad. Indian Council of Agricultural Research, New Delhi.

Anonymous (1981) Rabi and Kharif Report, All India Coordinated Rice Improvement Project, Hyderabad. Indian Council of Agricultural Research, New Delhi.

Balasubramanian, M.; Mohanasundaram, M.; Velusamy, R.; Subba Rao, P.V.; Janaki, I.P. (1978) Nira, a brown planthopper resistant variety. Int. Rice Res. Newslett. 3(2), 6-7.

Banerjee, S.N.; Diwakar, M.C.; Joshi, N.C. (1973) Plant protection problems in respect of high-yielding cereals of India. Sc. Cult. 39(4), 164-168.

Bentur, J.S.; Kalode, M.B. (1980) Biocontrol studies on leaf and planthoppers. pp.103-108. Proc. 3rd Workshop, All India Coordinated Research Project on Biological Control of Crop Pests and Weeds, Ludhiana, Indian Council of Agricultural Research, New Delhi.

Bentur, J.S.; Mangal Sain; Kalode, M.B. (1982) Studies on egg and nymphal parasites of rice planthoppers, Nilaparvata lugens (Stål) and Sogatella furcifera (Horvath). Proc. Indian Acad. Sc. (Anim. Sc.) 91, 165-176.

Channa Basvanna, G.P.; Gubbaiah, G.; Rai, P.S.; Mahadevappa, M. (1976) The rice brown planthopper Nilaparvata lugens Stål in Karnataka - India. Int. Rice Res. Newslett. 1(2), 14.

Chatterjee, P.B. (1971) Outbreaks and new records. Plant Prot. Bull., FAO, 19, 22.

Chaudhary, J.P.; Ramzan, M. (1968) Pachygonatopus sp. (Dryinidae: Hymenoptera), a new parasite of Sogatella furcifera Horvath (Delphacidae: Homoptera). Ind. J. Ent. 30, 317.

Dhawan, A.K.; Sajjan, S.S. (1976) Biology of the rice green leafhopper, Nephotettix nigropictus (Stål) (Cicadellidae: Hemiptera). J. Res. Punjab Agric. Univ. 13(4), 379-383.

Diwakar, M.C. (1975) Current entomological problems of paddy in new agricultural strategy, Sc. Cult. 41(1), 19-22.

Dutta, N.; Biswas, A.K. (1979) Contribution of antibiosis in locating tolerance of paddy varieties to Nephotettix virescens (Dist.) and N. nigropictus (Stål). J. ent. Res. 3(2), 196-211.

Dyck, V.A.; Misra, B.C.; Alam, S.; Chen, C.N.; Hsieh, C.Y.; Rejesus, R.S. (1979) Ecology of the brown planthopper in the tropics, pp.61-98. In Brown Planthopper: Threat to Rice Production in Asia, International Rice Research Institute, Los Banos, Philippines.

Fernando, H.; Senadhera, D.; Elikavela, Y.; de Alwis, H.M.; Kudagamage, C. (1979) Varietal resistance to the brown planthopper in Sri Lanka, pp.241-249. In Brown Planthopper: Threat to Rice Production in Asia, International Rice Research Institute, Los Banos, Philippines.

Freeman, W.H. (1976) Breeding rice varieties for disease and insect resistance with special reference to the brown planthopper, Nilaparvata lugens. Paper presented at Indian Science Congress, Visakhapatnam, India, 13pp. (mimeo.).

Ghauri, M.S.K. (1979) White backed planthopper attacks before introduction of new rice varieties in Pakistan. Int. Rice Res. Newslett. 4(5), 11.

Ghosh, A.; John, V.T.; Rao, J.R.K. (1979) Suspected ragged stunt disease in India. Int. Rice Res. Newslett. 4(3): 13.

Heinrichs, E.A. (1979) Control of leafhopper and planthopper vectors of rice viruses, pp.529-580. In Maramorosch, K.; Harris, K.F. (Ed.). Leafhopper vectors and Plant Disease Agents. Academic Press, Inc., New York.

Heinrichs, E.A.; Khush, G.S. (1978) Ragged stunt virus disease in India and Sri Lanka. Int. Rice Res. Newslett. 3(2), 13.

Israel, P. (1969) Integrated Pest Control for Paddy. Oryza 6(2), 45-53.

Israel, P.; Prakasa Rao, P.S. (1968) Harmonia arcuata Fabricius (Coccinellidae) - predatory on the rice planthoppers Sogatella furcifera Horvath and Nilaparvata lugens Stal, Curr. Sc. 37, 367-368.

Kabir, A.; Alam, M.S. (1981) Varietal screening for resistance to brown planthopper and its biotypes in Bangladesh. Int. Rice Res. Newslett. 6(5), 8-9.

Kalode, M.B. (1971) Biochemical basis of resistance or susceptibility to brown planthopper and green leafhopper in some rice varieties. Saturday Seminar, pp.17, International Rice Research Institute, Los Banos, Philippines (Mimeo.).

Kalode, M.B. (1976) Brown planthopper in rice and its control. Ind. Farm, 27(5), 3-5.

Kalode, M.B. (1980) The rice gall midge - varietal resistance and chemical control, pp.173-193. In Rice Improvement in China and other Asian Countries. International Rice Research Institute, Los Banos, Philippines.

Kalode, M.B.; Viswanathan, K.P.R.; Seshu, D.V. (1975) Standard test to characterise host plant resistance to brown planthopper in rice. Ind. J. Plant Prot. 3, 204-206.

Kalode, M.B.; Viswanathan, K.P.R. (1976) Changes in relative status of insect pests in rice. Ind. J. Plant Prot. 4, 79-91.

Kalode, M.B.; Krishna, T.S.; Pophaly, D.J.; Lakminarayana, A. (1977) Note on new multiple resistance to donors to major insect pests of rice (Oryza sativa L.). Ind. J. agric. Sc. 47, 626-627.

Kalode, M.B.; Krishna, T.S.; Gour, T.B. (1978) Studies on the pattern of resistance to brown planthopper (Nilaparvata lugens) in some rice varieties. Proc. Ind. nat. Sc. Acad. B 44, 43-48.

Kalode, M.B.; Krishna, T.S. (1979) Varietal resistance to brown planthopper in India, pp.187-199. In Brown Planthopper: Threat to Rice Production in Asia. International Rice Research Institute, Los Banos, Philippines.

Kalode, M.B.; Mangal Sain; Bentur, J.S.; Kondal Rao, Y. (1980) Recent investigations on host plant resistance in rice. Paper presented at seminar on Pest Management in Rice, Coimbatore, India. Abstracts, pp.23-24.

Kalode, M.B.; Bentur, J.S.; Mangal Sain; Prasad Rao, U.; Srinivasan, T.E. (1982) An improved method for field screening cultures resistant to brown planthopper. Int. Rice Res. Newslett. 7(1), 6-7.

Kannaiyan, S.; Jayaraman, V.; Jagannathan, R.; Palaniyandi, V.G. (1978) Occurrence of rice tungro virus in Tamil Nadu. Int. Rice Res. Newslett. 3(3), 8.

Koshiya, D.J.; Bhattacharya, A.K.; Verma, A.K. (1981) Efficacy of granular insecticides on different developmental stages of brown planthopper. Int. Rice Res. Newslett. 6(2), 16.

Krishnadoss, D.; Abdul Kareem, A. (1980) Studies on the toxicity of certain insecticides on Cyrtorhinus lividipennis (Reut.), a mirid predator on brown planthopper Nilaparvata lugens (Stål). Paper presented at seminar on Pest Management in Rice, Coimbatore, Abstracts, p.3.

Krishnaiah, N.V.; Kalode, M.B. (1980) Toxicological investigations against some important insect pests of rice. Paper presented at seminar on Pest Management in Rice, Coimbatore, Abstracts, pp.1-2.

Kulshreshtha, J.P.; Anjaneyulu, A.; Padmanabhan, S.Y. (1974) The disastrous brown planthopper attack in Kerala. Ind. Farm. 24(9), 5-7.

Manjunath, T.M. (1978) Two nematode parasites of rice brown planthopper in India. Int. Rice Res. Newslett. 3(2), 11.

Manjunath, T.M.; Rai, P.S.; Gowda, G. (1978) Parasites and predators of Nilaparvata lugens in India. PANS 24, 265-269.

Manjunath, T.M.; Urs, K.C.D. (1979) Empoascanara indica in paddy nurseries. FAO Plant Prot. Bull. 27-93.

Mishra, R.K.; Shanker, A. (1980) The 'knockdown speed' of insecticides against brown planthopper and green leafhopper. Int. Rice Res. Newslett. 5(6), 15-16.

Misra, B.C. (1975) Occurrence of a planthopper Unkanodes sapporonus Mats. (Delphacidae: Homoptera) as a new pest of rice in India. Oryza 12, 49.

Misra, B.C.; Israel, P. (1968) Leaf and planthoppers of rice. Int. Rice Comm. Newslett. 17(2), 7-12.

Misra, B.C.; Israel, P. (1970) The leaf and planthopper problems in high yielding dwarf varieties of rice. Oryza 7, 127-130.

Naik, R. (1979) Occurrence of rice ragged stunt disease in West Bengal, India. Int. Rice Res. Newslett. 4(2), 12.

Naik, R.; Misra, D. (1977) Screening of rice for resistance to tungro virus. Int. Rice Res. Newslett. 2(6), 7.

Nalinakumari, T.; Mamman, K.V. (1975) Biology of the brown planthopper, Nilaparvata lugens (Stål) (Delphacidae; Hemiptera). Agric. Res. J. Kerala 13, 53-54.

Narayanasamy, P.; Balasubramanian, M. (1977) Insecticidal control of brown planthopper in the field. Int. Rice Res. Newslett. 2(3), 9.

Natarajan, K.; Chandy, K.C. (1980) Screening for brown planthopper resistance. Int. Rice Res. Newslett. 5(4), 7-8.

Natarajan, K.; Palchamy, A. (1978) Outbreak of rice caseworm and brown planthopper in Madurai, Tamil Nadu, India. Int. Rice Res. Newslett. 3(3), 17.
Nath, D.K.; Sen, S.C. (1978) Brown planthopper in West Bengal, India. Int. Rice Res. Newslett. 3(1), 13.
Patel, R.K.; Tiwari, R.D. (1967) Note on Delphacid menace on paddy. Ind. J. agric. Res. Sc. 37, 456-457.
Pathak, M.D.; Dhaliwal, G.S. (1981) Trends and strategies for rice insect problems in tropical Asia. IRRI Research paper series No. 64, 15pp. International Rice Research Institute, Los Banos, Philippines.
Pathak, P.K.; Lal, M.N. (1976) Varietal resistance to brown planthopper Nilaparvata lugens (Stål) and its biotypes. Int. Rice Res. Newslett. 1(2), 8.
Pathak, P.K.; Verma, S.K. (1980) Distinct geographic populations of brown planthopper in India. Int. Rice Res. Newslett. 5(1): 12.
Pathak, P.K.; Verma, S.K.; Lal, M.N. (1978) Varietal resistance to brown planthopper and problems of its biotypes. Ind. J. Gen. Plant Breed. 39A, 141-142.
Pawar, A.D. (1981) Sugarcane pyrilla attacking rice, and its biological control in India. Int. Rice Res. Newslett. 6(3), 17.
Pillai, K.G.; Kalode, M.B.; Rao, A.V. (1979) Effects of nitrogen levels, plant spacings and row orientation on the incidence of the brown planthopper of rice. Ind. J. agric. Sc. 49, 125-129.
Pophaly, D.J.; Bhaskar Rao, T.; Kalode, M.B. (1978) Biology and predation of the mirid bug, Cyrtorhinus lividipennis Reuter on plant and leafhoppers in rice. Ind. J. Plant Prot. 6, 7-14.
Pradhan, S. (1971) In tropics protection research more needed than production research. Ind. J. Entomol. 33, 233-259.
Pradhan, S. (1975) The revolution in agriculture and pests. Entomol. Newslett. 5(3), 19.
Prakasa Rao, P.S. (1977) Combined field resistance of some 1975 IRON entries to green leafhopper and stem borer at Cuttack, India. Int. Rice Res. Newslett. 2(4): 4.
Prakasa Rao, P.S.; Israel, P.; Krishna, A.G. (1976) Brown planthopper attack in East Godavari, A.P., India. Int. Rice Res. Newslett. 1(2), 17.
Prasad Rao, R.D.V.J.; John, V.T. (1973) Alternate host of rice tungro virus and its vector. Plant Disease Report 58, 856-860.
Rajendran, B.; Narayanasamy, P. (1978) Occurrence of the brown planthopper on rice in Pondicherry region, India. Int. Rice Res. Newslett. 3(5), 16.
Rao, G.M.; Shukla, V.D.; Anjaneyulu, A. (1977) Using carbofuran against the rice tungro virus vector in India. Int. Rice Res. Newslett. 2(1), 9.
Rao, P.R.M.; Prakasa Rao, P.S. (1980a) Evaluation of lethal concentration of different insecticides against the brown planthopper. Int. Rice Res. Newslett. 5(2), 15.
Rao, P.R.M.; Prakasa Rao, P.S. (1980b) Evaluation of depth and effective zone of placement of carbofuran for brown planthopper control. Int. Rice Res. Newslett. 5(3), 15.

Reddy, D.B. (1973) High yielding varieties and special plant protection problems with particular reference to tungro virus of rice. Int. Rice Comm. Newslett. 22, 34-42.

Reddy, K.V. (1979) Varietal resistance to brown planthopper Nilaparvata lugens (Stål) (Homoptera: Delphacidae) in rice. M.Sc.(Ag.) thesis, Andhra Pradesh Agricultural University, Hyderabad, 72pp.

Samal, P.; Misra, B.C. (1977a) Notes on the life history of Cyrtorhinus lividipennis Reuter, a predatory mirid bug of rice brown planthopper Nilaparvata lugens (Stål) in Orissa. Oryza 14, 47-49.

Samal, P.; Misra, B.C. (1977b) A short note on biology of spider, Marpissa pomatix (Walckenaer) feeding on brown planthoppers Nilaparvata lugens (Stål) in the rice field of C.R.R.I., Cuttack. Oryza 14, 133-134.

Samal, P.; Misra, B.C. (1978) Notes on the egg parasites of the brown planthopper Nilaparvata lugens (Stål) in Orissa. Oryza 15, 96-98.

Samal, P.; Misra, B.C.; Nayak, P. (1978) Entomophthora fumosa Speare, An entomogenous fungus on rice brown planthoppers. Curr. Sc. 47, 241-242.

Samal, P.; Misra, B.C. (1982) Biological notes on the waterstrider, Limnogonus nitidus (Mayr), a predator on rice brown planthopper, Nilaparvata lugens (Stål). Ann. ent. Soc. Am. 75, 12-13.

Seetharaman, R.; John, V.T. (1981) Studies on rice virus diseases with special emphasis on breeding for resistance. Final technical Report - PL 480 Project, 87pp. All India Coordinated Rice Improvement Project (ICAR), Hyderabad, India.

Seshu, D.V.; Kauffman, H.E. (1980) Differential response of rice varieties to the brown planthopper in international screening tests. IRRI Research Paper Series No. 52, 13pp., International Rice Research Institute, Los Banos, Philippines.

Shastry, S.V.S. (1971) Breeding for resistance to pests and diseases. Paper presented at Symposium on Rice Production under Environmental Stress (Mimeo.).

Shukla, K.K. (1979) Occurrence of a new insect small brown planthopper, Laodelphax striatellus (Fallen) in India. Curr. Sc. 48, 548.

Sidhu, G.S. (1979) Need for varieties resistant to the white backed planthopper in the Punjab. Int. Rice Res. Newslett. 4(1), 6-7.

Singh, K.G. (1971) Studies on transmission of penyakit merah virus disease of rice. Malaysian J. Agric. 42, 94-103.

Srivastava, R.P.; Nayak, P. (1978) A white muscardine disease on brown planthopper of rice. Curr. Sc. 47, 355-356.

Sukhani, T.R. (1971) Pest incidence on paddy. Entomol. Newslett. 4(6), 7.

Vaidya, G.R. (1978) Varietal resistance to white backed planthopper Sogatella furcifera. M.Sc.(Ag.) thesis, Andhra Pradesh Agricultural University, Hyderabad, 107pp.

Vaidya, G.R.; Kalode, M.B. (1981) Studies on biology and varietal resistance to white backed planthopper Sogatella furcifera (Horvath) in rice. Ind. J. Plant Prot. 9, 3-12.

Velusamy, R.; Janaki, I.P.; Subramanian, A. (1975) Occurrence of brown planthopper in Coimbatore District, India. Rice Entomol. Newslett. 3, 3.

Venkateswarlu, B.V.; Kalode, M.B. (1981) Influence of narrow and broad leaf canopies on population dynamics of brown planthopper (N. lugens) in rice. Ind. J. Plant Physiol. 24, 183-192.

Venkata Swamy, V. (1976) Studies on the biology and effectiveness of various insecticides against brown planthopper Nilaparvata lugens (Stål) (Delphacidae: Homoptera). M.Sc.(Ag.) thesis, Andhra Pradesh Agricultural University, Hyderabad, 69pp.

Venkata Swamy, V.; Kalode, M.B. (1979) Biology of brown planthopper Nilaparvata lugens (Stål) on different plant species. Pestology 3(10), 26-29.

Venkata Swamy, V.; Kalode, M.B. (1981) Effectiveness of various insecticide formulations against brown planthopper Nilaparvata lugens (Stål). Pesticides 15(2), 10-14.

Verma, S.K.; Pathak, P.K.; Singh, B.N.; Lal, M.N. (1979a). Susceptibility of promising rice cultivars to white backed planthopper. Int. Rice Res. Newslett. 4(2), 8.

Verma, S.K.; Pathak, P.K.; Singh, B.N.; Lal, M.N. (1979b) Indian biotypes of the brown planthopper. Int. Rice Res. Newslett. 4(6), 7.

Viswanathan, P.R.K. (1977) Varietal resistance and host specificity of rice green leafhoppers Nephotettix virescens (Distant) and N. nigropictus (Stål). Ph.D. thesis, Osmania University, Hyderabad, 198pp.