INTERNATIONAL JOURNAL OF PLANT PROTECTION
VOLUME 7 | ISSUE 2 | OCTOBER, 2014 | 465-475 • e ISSN-0976-6855 | Visit us : *www.researchjournal.co.in*

IJPP

A REVIEW

DOI : 10.15740/HAS/IJPP/7.2/465-475

Evaluation of rice varieties for resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath)

■ M.N. LAL **AND** ARUN KUMAR SINGH*

Department of Entomology, Narendra Dev University of Agriculture and Technology, Kumarganj, FAIZABAD (U.P.) INDIA

ARITCLE **I**NFO

Received : 27.12.2012
Accepted : 19.09.2014

KEY **W**ORDS :
Whitebacked planthopper, *Sogatella furcifera*, Rice, Resistant variety, Pest management

***Corresponding author:**
Email: singharunent@gmail.com

ABSTRACT

The development of insect–resistant high yielding varieties considered as a breakthrough in the modern production technology. Resistant varieties of plants offer an inexpensive preventive measure, generally compatible with chemical and nonchemical methods of pest control. These can be integrated with other methods in developing appropriate pest management programme. In view of the spectacular success achieved in reducing pest population, greater emphasis is now placed on the development of resistant varieties. The work on development of resistant varieties of rice whitebacked planthopper (WBPH) *Sogatella furcifera* (Horvath) has been stepped up only in last two decade and has led to the identification of several resistant sources.

How to view point the article : Lal, M.N. and Singh, Arun Kumar (2014). Evaluation of rice varieties for resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath). *Internat. J. Plant Protec.*, **7**(2) : 465-475.

The whitebacked planthopper (WBPH) *Sogatella fucifera* (Horvath), a minor pest so far, has become increasingly important in many Asian Countries. The development of resistant of rice varieties to *S. furcifera* has been stepped up only in last decade and has led to the identification of several promising sources against this insect. There is evidence that *S. furcifera* biotypes also exist as screening for resistance has indicated differential reactions in South and South-East Asia. Thus, there is a need to evaluate rice varieties at different places to assess the level of resistance to the population existing in those areas. Further, it is important to utilize varieties for breeding which have adequate levels of resistance to the local population of insect. In an effort to know the progress in development of resistant varieties to *S. furcifera*, the results of screening has been reviewed in this paper.

Field screening for resistance :

Early studies on varietal resistance were mainly based on field population levels of *S. furcifera*. Atwal *et al.* (1967) recorded population of this hopper on a number of rice varieties at Kapurthala, Punjab and found IR 48, IR 52 and Jhona harbouring lower populations compared to TN 1. Patel and Tiwari (1967) indicated Nusahi as resistant out of 3 varieties tested at Chhattisgarh region of Madhya Pradesh. Kittur and Patel (1968) also indentified 11 varieties as having lower infestation by *S. Furcifera* in field experiments at Raipur, Madhya Pradesh. Out of 34 fine grained varieties of rice screened 5 varieties *viz.*, PR 106, PR 445, PR 560, PR 561, PR 563 were resistant under field conditions in Punjab (Dhaliwal *et al.*, 1979). Verma *et al.* (1979) indicated 2 varieties *viz.*, RP 633- 519-1-3-4-1 and IR 36 harbouring low population of *S. furcifera* at Pantnagar. Of 16 cultivars tested, RP 79-8-3-2-1 had the lowest number of *S. furcifera* nymphs in Haryana (Kushwaha *et al*., 1982 b). Dhaliwal *et al*. (1984) observed the reaction of 39 varieties in the field and 3 varieties *viz.,* IR 9224-117-2-3-3, IR 19728-9-3-2 and Kalyan were found resistant. In a separate test, screening of 43 rice varieties resulted in the identification of BR 51-282-8, PAU 269-1-9-2-5, RP 5-3, HAV 11-12, PAU 269-1-9-2-3, UPR 277-9-2-1 and PAU 269-1-8-4-1-B-2 as resistant ones (Dhaliwal *et al*., 1984).

From the observations on the incidence of *S. furcifera* in 28 rices, varieties namely, UPR 79-104 and indrasan were found harbouring significantly low population in the field. Pathak *et al.* (1986) also identified veluthachera as resistant under field conditions. Of 31 rice varieties screened in the field, 8 entries *viz*., Rathu Heenati, Mudu Kriyal, Eswaramangalam, MO1, ARC 7080, Anaikomban, ARC 5984 and PTB 33 were resistant (Reddy *et al*., 1985).

Kushwah *et al.* (1986) evaluated 43 varieties for field resistance to *S. furcifera* and 18 varieties, namely, RP 2068-18-3-5, RP 2068-17-3-7, RP 2068-18-3-5, RP 2068-17-3-7, RP 2068-17-3-7,CO 29, IET 8817 (CR 372-487), Vaizhaepoo Samba, RP 2069-3-4-4-6, RP 2068-18-2-6, RP2068-16-9-5, RP 2068-18-4-7,T 2005, RP 2068-12-1-8-1 and RP 2068-15-1-4-2 were identified as resistant based on 0-9 scores in mass screening under field conditions.

A large number of varieties have been screened under multilocational co-ordinated trials and a good number of varieties have been found promising against *S. furcifera* under field conditions.

Greenhouse screening :

The mass screening of rice varieties for resistance to *S. furcifera* under glasshouse conditions was first initiated at IRRI in 1970 (IRRI, 1971). Using the seedling bulk test (Athawal *et al*., 1971), 1500 varieties were screened and 26 were found to be resistant (Rodriguez-Rivera, 1972). In another phase of mass screening, a total of 6715 rice varieties from the germplasm bank of IRRI were screened and 128 were identified as resistant (Pablo, 1977). More than 36,000 rice varieties were screened till 1981 and nearly 270 were identified as resistant (Saini *et al.*, 1982). Screening work was further accelerated and from screening of 40,000 rice varieties about 300 resistant sources were identified in the last 12 years (Heinrichs and Rapusas, 1983). So far, 48,554 accessions were tested for resistance to *S. furcifera* and 401 (0.8%) selected as resistant (IRRI, 1985; Heinrichs *et al.*, 1985 and 1986; Khan and Saxena, 1986 and Romena *et al.*, 1986).

In India, the greenhouse screening of varieties was first undertaken at AICRIP, Hyderabad in 1976 (Kalode *et al*., 1977). Because of the increased importance of *S. furicfera* in some of the states, the trial consisting of 36 entries was formulated for the first time for testing them at few locations to identify sources of resistance to this insect. Of 36 entries screened at Rajendranagar, Hyderabad, 11 varieties were found to be resistant (AICRIP, 1979). Subsequently 536 varieties were evaluated for resistance at Rajendranagar and 41 varieties were identified as promising in preliminary test but 29 per cent of these did not exhibit resistance in replicated tests (Kalode *et al.*, 1977). The screening programme was expanded further in national Rice improvement programme and 110 varieties were evaluated at 5 locations *viz*., Rajendranagar, Ludhiana, Pantnagar, Coimbatore and Kapurthala and 10 varieties were identified promising with low damage based on the results of 3 or more locations (AICRIP, 1980). Sixty six tall traditional varieties identified as promising to *N. lugens* at Hyderabad were also screened against *S. furcifera* and 46 entries were found promising to this insect (Krishna *et al.*, 1980). A total of 222 rice accessions from 7 countries were evaluated for resistance at Coimbatore and 86 accessions were identified as promisisng to *S. furcifera* (Gunathilagaraj, 1983 and Gunathilagaraj and Chelliah, 1984). In a separate study 100 rices received form IRRI were screened and 15 were resistant to *S. furcifera* . A collection of 887 cultivars was screened at ludhiana and 34 were found to be resistant (Gupta and Shukla, 1985). Thirty one rice accessions were also evaluated and 4 entries were resistant and 15 as moderate resistant.

In a study on varietal resistance to *S. furcifera* varieties of rice were evaluated and 36 were found promising at Pantnagar (Lal, 1981 and Lal *et al.*, 1983). Subsequently 133 rices were screened and 27 were identified promising to *S. furcifera* (Kaul, 1985). In a separate test, 28 rices were screened and 9 were found resistant (Pathak *et al.*, 1986). Later from screening of 347 varieties, 124 were identified promising showing moderate resistant to resistant reaction against *S. furcifera* (Lal, 1988).

In India several research centres have identified resistant sources against *S. furcifera* and some of the resistant cultivars identified at DRR and other centres are listed in.

More that 400 traditional varieties with *S. furcifera* resistant have been identified in greenhouse screening at IRRI and in National programmes in South and South-East Asia (Heinrichs *et al.*, 1986). Out of 401 rices selected for resistance to *S. furcifera* at IRRI, 351 (88 %) were from India, Pakistan and Nepal (Khan and Saxena, 1984a and Romena *et al*., 1986). Some of the cultivars with potential resistance identified at IRRI are given in Table 3.

Although many rice varieties have been identified as resistant in several Asian countries, none have so far released for large scale cultivation (Khush and Choudhary, 1981).

Evaluation of resistant varieties :

Sometimes in evaluation tests the level of resistance to

S. furcifera has occasionally been inconsistent among cultivars rated resistant on the basis of seedling bulk test. Kim *et al*. (1982) reported dissimilarities in the results of the free-choice seedling bulk test and population buildup studies for evaluating resistance to *S. furcifera* in some rice cultivars in Korea. They found that rice cultivars rated as resistant or moderately resistant 7 days after infestation became susceptible after 23 days. Heinrichs and Rapusas (1983) reported similar differences in *S. furcifera* damage ratings recorded after 5 days and 13 days of infestation. Khan and Saxena (1984 a,b) demonstrated that this inconsistency in damge rating was due to an imbalance in infestation level *i.e.* shortly after seedlings are infested, nymphs tend to move over to susceptible check cultivars. In a free- choice test, therefore, the escape of a test, cultivar may be misconstrued for true or genetic resistance. To avoid this shortcomings, Khan and Saxena (1984 a,b) conducted a no-choice seedling bulk test in which each row of test exposed to equal level of infestation. Rice varieties Podiwi A–8 and N–22, rated as moderately resistant and resistant in the free–choice test, proved susceptible and moderately resistant, respectively, in the non-choice test, Singh *et al*. (1984) also reported differences in damage ratings in free-choice tests.

The variety Podiwi A–8 rated as moderately resistant in free-choice test became susceptible in non-choice test.

In addition to the seedling bulk test, various techniques have been used for testing of cultivars. Other techniques such as seedling mortality test, seedling screening in pots and alternate row testing were employed to measure the resistance to *S. furcifera* in rice varieties (Gunathilagaraj, 1983; Gunathilagaraj and Chelliah, 1984 and Lal, 1988). They found some or less identical results, when cultivars were tested by these methods.

The conventional seedling screening is mostly a qualitative test. A modification of the standard seedling screening test was developed which detects resistance at an older plant age. Varieties identified as resistant in the modified seedling test (Heinrichs and Kalode, 1985) .

Mechanism of resistance :

The nature of varietal resistance to insect pest is made of any one or some combination of 3 broad categories: non-preference, antibiosis and tolerance (Painter, 1951).

Several workers have studied the mechanism of resistance to *S. furcifera* in rice varieties. These studies revealed that non-preference and antibiosis or a combination of both operate in resistance (Choi *et al*., 1973; Pablo, 1977; Kalode *et al.*, 1977; Lal, 1981 and 1988 and Gunathilagarj and Chelliah, 1985a). All the tolerance mechanism of resistance to *S. furcifera* was also included in one of the earlier studies (Lal, 1988).

Preference/ non- preference :

Nymphal preference :

A greater preference of *S. furcifera* nymphs for settling on susceptible varieties than on resistant ones was reported (Vaidya and Kalode, 1981, Choi *et al.*, 1982; Khan and Saxena, 1985 and Lal, 1988). Gunathilagaraj and Chelliah (1985a) observed differences in nymphal preference at 24 hrs after infestation when upto three times more nymphs settled on susceptible than on resistant varieties. The scattered nymphs spent some time in locating the preferred varieties. Apparently due to visual or olfactory response the nymphs were equally attracted to different varieties but their feeding was not sustained on some of these varieties. This might have forced the nymphs to move to the preferred varieties. This view was earlier presented indicating the gustatory stimuli as an important factor in determining the preference or non- preference of the hoppers to rice varieties (IRRI, 1977; Pablo, 1977; Gunathilagaraj and Chelliah, 1985a and Lal, 1988). Vaidya and Kalode (1981) indicated that the nymphs were able to move away from resistant varieties within 2 hours after caging.

Adult preference :

The varietal preference by *S. furcifera* female was observed by several workers (IRRI, 1972; Pablo, 1977; Vaidya and Kalode, 1981; Gunathilagaraj and Chelliah, 1985c and Lal, 1988). A greater preference for settling on susceptible varieties than on esistant ones has been reported for *S. furcifera* adults (Rodrgenez- Rivesa, 1972; Pablo, 1977; Choi *et al.*, 1982; Khan and Saxena, 1985 and Lal, 1988). The differences in preference for varieties became more susceptible tn1 harboured 2.5 to 3.5 times more insects than the resistant varieties (Gunathilagaraj and Chelliah, 1985 a).

Ovipositional preference :

Ovipositional preference of *S. furcifera* for the susceptible TN 1 than on resistant ones has been reported by many workers (IRRI, 1972–1977; Rodrigues-Rivea, 1972; Pablo, 1977; Vaidya and Kalode, 1981 and Lal, 1988). Choi *et al.* (1982) indicated that the ovipositional preference of *S. furcifera* differed from variety to variety, but there was no definite trend. Pablo (1977) also reported that in an ovipositional preference test, out of 25 resistant and susceptible varieties, 20 received almost equal numbers of eggs. Preference by *S. furcifera* females was also directly related to the adults attracted on the varieties (Lal, 1988). *S. furcifera* laid eggs in the leaf sheath than in the leaf blade (Guanthilagaraj and Chelliah, 1985 and Lal, 1988). Khan and Saxena (1985) indicated that the ovipositional response of *S. furcifera* was identical I susceptible and resistant varieties. Ovipositional preference of *S. furcifera* was attributed to the chemical stimuli by certain amino acids (Miyake and Fujiwara, 1961) and high chlorophyll content (Miyake and Fujiwara, 1962). However, preference for feeding shelter or ovipositional was not always related to each other (Rodriguez- Rivera, 1972).

Feeding preference :

Studies on feeding preference revealed that the insect made more feeding marks in both the leaf sheath and leaf blade of resistant plants than in susceptible plants (Rodriguez-Rivera, 1972; Pablo, 1977; Gunathilagaraj, 1983 and Lal, 1988). Pablo (1977) indicated that the resistant provided the insect a feeding stimulus nut could not sustain feeding which might be due to the presence of certain chemical substances which inhibit feeding.

Antibiosis :

The adverse effects of resistant varieties on the growth and development of nymphs, adult survival and reproduction, feeding rate and population growth indicate the operation of antibiosis factors. The resistant varieties adversely affected *S. furcifera* nymphal growth and adult longevity and fecundity (Choi *et al*., 1973, 1982; Lee and Park, 1976; Heinrichs and Rapusas, 1983; Gunathilagaraj, 1983; Khan and Saxena, 1985 and Lal, 1981, 1988).

Growth and development :

Nymphal survival :

Non–preferred varieties limiting the feeding and consequent survival were reported by several workers (IRRI, 1972; Rodriguez-Rivea, 1972; Pablo, 1977 and Lal, 1981, 1988). The survival of the nymphs on resistant varieties varied between 50 to 70 per cent in contrast to the nearly 100 per cent survival on the susceptible TN 1 at 6 days after caging and these differences became wider at 14 days after caging (Rodriguez-Rivera, 1972). Pablo (1977) reported that the percentage survival of nymphs on resistant varieties ranged from 12 to 55 per cent and T_1 had 76 per cent survival at 15 days after infestation. Pathak (1977) indicated that 99 to 100 per cent first instar nymphs survival on the susceptible TN 1, whereas on resistant ARC 5762 it was 30 to 70 per cent. In another study, nymphal survival averaged 15 to 20, 60 and 73 to 100 per cent on resistant, moderately susceptible and susceptible varieties, respectively (Choi *et al*., 1973). The similar trend of survival was observed in a study conducted by Kalode *et al.* (1977) who reported that the survival of nymphs ranged from 50 to 54 per cent an ARC 5955, ARC 11208 and ARC 11321 as compared to 100 per cent on TN 1 at 3 days after caging. The survival further decreased when observations were taken on 9 th day and it was only 10 per cent on ARC 5955 as compared to 45 to 64 per cent on resistant varieties and TN 1 had 75 per cent survival (Vaidya and Kalode, 1979). In an earlier study, Lal (1981) observed significantly low nymhal survival on resistant (24 to 52 %) and moderately resistant (68 to 76 %) varieties as compared to 96 per cent survival on the susceptaible TN 1. In another study, the percentage nymphal survival ranged from 18 to 40 and 52 to 62 per cent on resistant and moderately resistant varieties on 12^{th} day and 12 to 28 and 36 to 48 per cent on 20^{th} day after infestation, whereas TN 1 had 92 per cent on the 12^{th} day and 72 per cent on the 20^{th} day after infestation (Lal, 1981). Similarly the lower survival of nymphs was indicated by Kaul (1985) on resistant and moderately resistant varieties as compared to the susceptible TN 1. Heinrichs and Rapusas (1983) reported significantly lower survival of nymphs on ARCA 10239, ADR 52 and IR 2035-117-3 than on the susceptible TN 1 at 12 days after infestation. The nymphal survival varied among the differenr resistant varieties ranging from 46 to 82 per cent at 3 days after caging, whereas it was 92 per cent of the susceptible TN 1 (Gunathilagaraj and Chelliah, 1985a). The survival of nymphs was lowest on resistant varieties followed by moderately resistant and then on susceptible varieties (Lal, 1988 and Ramaraju *et al.,* 1989).

Choi *et al.* (1973) and Lee and Park (1976) opined that the lower rate of adult emergence from the resistant varieties might be due to the higher nymphal mortality on these varieties as compared to the susceptible ones. The adult formation ranged from 21 to 49 on resistant varieties as compared to 96 per cent on TN 1 (Lee and Park, 1976). Lal (1981) also indicated significant differences in adult formation among resistant, moderately resistant and susceptible varieties. The lower adult emergence on resistant varieties was due to the higher mortality of nymphs. Significantly low percentage of nymphs becoming adults on resistant variety IR 2035-117-3 as compared to TN 1 was recorded by several workers (Heinrichs and Rapusas, 1983; Khan and Saxena, 1985a and Rapusas and Heinrichs, 1985). Lal (1988) observed lower adult emergence on resistant varieties followed by moderately resistant varieties than on susceptible varieties.

Nymphal development :

The antibiotic effects of resistant varieties prolonged the development period of nymphs of *S. furcifera* (Rodriguez-Rivera, 1972; Choi *et al*., 1973; Pablo, 1977; Vaidya and Kalode, 1981; Lal, 1981, 1988 and Ramaraju *et al*., 1989). Pablo (1977) observed that development period was prolonged by 4 to 6 days on resistant varieties as against the susceptible TN 1 and that females had longer development period than the males.

The nymphal development period ranged from 14.7 to 16.0, 11.6 and 10.0 to 10.6 days on resistant, moderately resistant and susceptible varieties, respectively (Choi *et al*., 1973). Lal (1981) observed nymhal period to be 3 to 7 days longer on resistant varieties than on the susceptible TN1. Heinrichs and Rapusas (1983) reported that the development period was longest on IR 2035-117-3 (16.1 days) and shortest on the susceptible TN 1 (12.5 days). The similar trend of nymphal period on these two varieties was recorded in different studies (IRRI, 1985; Khan and Saxena, 1985 and Rapusas and Heinrichs, 1985). Gunathilagaraj and Chelliah (1985a) reported much longer nymphak duration on the resistant varieties (14.72 days). The nymphal period was prolonged by about 3 to 5 days on resistant varieties as compared to susceptible varieties (Lal, 1988).

Adult longevity :

The adult longevity is also influence adversely by resistant varieties and the life span of *S. furcifera* on resistant varieties was significantly shorter than on the susceptible TN 1 (IRRI, 1972 and Rodridguez-Rivera, 1972). The adult longetivity varied from 5.1 to 12.6 days for male and 2.2 to 9.7 days for female on resistant varieties and 27.2 days for male and 17.9 days for female on the susceptible TN 1 (IRRI, 1972 and Rodriguez- Rivera, 1972). However, it was obvious from late studies that the females outlived the males (Choi *et al.*, 1973; IRRI, 1977; Pablo, 1977; Lal, 1981 and Gunathilagaraj and Chelliah, 1985a). Pablo (1977) observed that the adults had a shorter life, being 2 to 9 days for male and 3 to 31 days for female on resistant varieties and 3 to 31 days for male and 6+ to 65 days for female on the susceptible TN 1. Similarly the adult longevity recorded by Lal (1981) was shorter (5.67 to 12.00 days), intermediate (14.00 to 14.50 days) and longer (17.17 days) on resistant, moderately resistant and susceptible varieties, respectively. Khan and Saxena (1985) also reported significantly shorter adult longevity on resistant varieties than on the susceptible TN 1. The males lived of 6 days on IR 2035-117-3 and 14.2 days on the susceptible TN 1, whereas for females, the longevity was 504 days and 26.2 days, respectively, which was several times higher than their longevity on resistant varieties. The longevity on resistant varieties varied from 302 to 7.0 days for females and from 3.8 to 5.2 days for males (Gunathilagaraj and Chelliah, 1985a). The adult longevity of both sexes was significantly shorter on resistant varieties (2.8 to 8.1 days) than on susceptible varieties on wich it varied from 15.4 to 19.0 days (Lal, 1988).

Fecundity :

Reduced fecundity on resistant varieties was reported by many workers (IRRI, 1972, 1977; Rodriguez-Rivera, 1972; Pablo, 1977; Lal, 1981, 1988 and Gunathilagaraj and Chelliah, 1985a). Rodriguez-Rivera (1972), correlated the number of eggs laid with the longevity of the female in different varieties and the insect laid about 10 to 70 times more eggs than those in the resistant varieties. On an average a female laid 505.4 eggs on TN 1, while number of eggs laid varied from 7.1 to 68.9 per female on resistant varieties. In another study, Pablo (1977) indicated that the average number of eggs laid on the susceptible TN 1 was 162, while 6 to 11 eggs were laid on the resistant varieties. A significant difference in fecundity was also observed by Lal, 1981 and higher numbers of eggs (167.80 per female) were noticed on the susceptible varieties TN 1 then on the moderately resistant and resistant varieties (6.40 to 28.20 per female).Gunathiagaraj and Chelliah (1985a) reported that fewer eggs were laid on the resistant varieties (153.4 to 204.2), while 272.6 eggs per female was laid on TN 1. Lal (1988) also observed difference in fecundity on resistant, moderately resistant and susceptible variety. The fecundity on resistant varieties was low (12.6 to 46.60) as compared to susceptible varieties on which it was highest (129.4 to 242.4).

Egg hatching :

Despite indiscriminate egg–laying by *S. furcifera* females on resistant and susceptible varieties, egg hatchability was markedly reduced on resistant varieties (Rodriguez-Rivera, 1972; Lal, 1981, 1988 and Khan and Saxena, 1985). In contrast, other studies indicated that hatchability of eggs was not affected by varietal resistance (Heinriches and Rapusas, 1983 and Gunathilegaraj and Chelliah, 1985a). Pablo (1977) found that hatching was not affected by resistant varieties but the physical and chemical environment of the plant tissues surroundings the *S. furcifera* eggs, especially on 60- day-old plants of the resistant variety Colombo affected hatching.

Feeding :

Several methods to determine the feeding activity of hoppers on resistant and susceptible plants have been developed (Paguia *et al.*, 1980 and Pathak and Heinrichs, 1982). The reduced feeding on resistant plants resulted in the small amount of honeydew excreted and low gain in insect weight (Lal, 1988).

In an earlier study, pre-starved females of *S. furcifera*, when allowed to feed on resistant varieties, excreted significantly less amount on honeydew than the susceptible TN 1 at 304 and 60 days old plants (Lal, 1981 and Lal *et al.*, 1988). The amount of honeydew excreted when feeding on resistant varieties was several time less as compared to the susceptile TN 1 (IRRI, 1977, 1981, 1982). Heinrichs and Rapusa (1983), reported that the honeydew excreted on susceptible varieties was about 30 times more than that on resistant varieties. The feeding rate by *S. furcifera* on both resistant and susceptible varieties varied with the stage of plants and it was negatively correlated with increasing age of plants (Lal, 1988).

Ingestion and assimilation of food :

Differences in relative susceptibility of resistance of plants to insects are determined by factors which influence the process of establishment of insect population on them (Saxena, 1969). The extent of insect establishment depends on an interaction between insect responses to various plant characteristics. Six main categories of insect's behavioural and physiological responses have been considered important during insect establishment on plants (Saxena, 1969) : (1) Orientation and settling, (2) feeding, (3) metabolism of ingested food, (4) growth, (5) survival of adults and egg production and (6) oviposition. Saxena and Pathak (1977) identified egg hatchability as another important factor during establishment of insect particularly by those which deposit their eggs inside the plant tissue. Interruption of one or more of these insect responses due to unfavourable plant characters would render the plant resistant.

Using the parafilm sachet technique for quantitative determination of food intake and utilization of ingested food by *S. fucifera* females, the quantity of food ingested and assimilated was significantly higher on susceptible rice plants than on rsistant ones (IRRI, 1985 and Khan and Saxena, 1985).

Recently, Khan and Saxena (1984a, b) used a DC variety of an electronic system for monitoring insect feeding to confirm *S. furcifera* resistance in selected rice varieties. The electronically recorded wave forms showed that *S. furcifera* probed readily and fed for longer periods on susceptible plants, while on resistant varieties, the insect made brief and repeated robes that reduced the ingestion period.

Population growth :

The cumulative effect of resistant varieties on *S. furcifera* population was observed by several workers (Pathak, 1971; Rodriguez-Rivera, 1972; Pablo, 1977; Vaidya and Kalode, 1979, 1981; Lal 1981, 1988, and Kaul, 1985). In earlier investigation by Lal (1981), the population buildup from 10 first instar nymphs of *S. furcifera* was significantly lower on resistant varieties (4.40 to 11.40) and moderately resistant varieties (27.60 to 59.40) than on the susceptible TN 1 (278.40). Similarly Gunathilagaraj and Chelliah (1985a) reported that the significant differences in population buildup from 10 first instar nymphs of *S. furcifera* released on 30-45 and 60 days old plants. On an average, the resistant varieties reduced the population by 1.35 to 14.4 fold. Kim *et al.* (1982) indicated that even the resistant varieties could support high population build-up and observed a decline in population levels 40 days after infestation. The low population level on resistant varieties was represented by the adverse effects of resistant varieties on the longevity and fecundity of adults and survival of nymphs (Gunathilagaraj and Chelliah, 1985a and Lal, 1988) found that the rate of population growth on different ages of plants had no influence in the expression of resistance.

Population growth was also considered as an important criterion for assessing the level of resistance (IRRI, 1981). Population growth produced from 5 pairs of adults of *S. furcifera* was lowest (33) on IR 2035-117-3 as compared with 559 on the susceptible TN 1 at 30 days after infestation on 30-day old plants (Heinriches and Rapusas, 1983). Khan and Saxena (1985) also indicated thtalation increases was significantly lower on all resistant cultvars that than on the susceptible TN 1. Similar pattern of population growth was also reported by other workers (Heinriches and Rapusas, 1985 and Lal, 1988).

The increase in population was depended on the combined effect of feeding rates, nutritional value of food, ovipositional rate and adult survival (Khan and Saxena, 1985).

Tolerance :

Tolerance refers to a basis of resistance in which the host plant exhibits an ability to grow and reproduce normally or to repair injury to a marked degree in spite of supporting a population approximately equal to that of severely damaging a susceptible host (Painter, 1951).

Of the three mechanisms of resistance categorized by Painter (1951), non- preference and antibiosis are considered of empirical values since they influence insect populations. In earlier studies on the mechanisms of varietal resistance in rice, tolerance was considered in terms of an important agronomic characteristics which implies a relationship between insects and the plants and the evaluation of this component was only based on yield (Pablo, 1977). An important consideration for not including in the studies has been tolerant varieties provide an ideal harbourage for insects and pathogen whose resulting populations may eventually become so large as to be controllable potential sources of infestation. However, to cope with the biotype problem.

Horber (1972) appreciated the usefulness of tolerance as "tolerance has value in preventing the buildup of new biotypes and in maintaining natural predators and parasites".

Recently rice varieties having a moderate level of resistance to *N. Lugens*, were evaluated to determine the mechanisms of resistance (IRRI, 1983). Panda and Heinriches (1983) studied in the greenhouse the levels of antibiosis and tolerance of moderately resistant varieties using parameters plant damage ad plant weight loss due to *N. Lugens* feeding were measured as tolerance indicators and *N. Lugens* dry weight produced through feeding on the varieties was used as and antibiosis indicator. Taking plant damage and plant weight loss as parameters to find out the tolerance nature of plants, Lal (1988) found good tolerance of IET 6288. CR 333-6-1, CR 333-6-2 and RP 1800-10-5-8-2 which were resistant to *S. furcifera.*

Biochemical basis of resistance :

Various workers have emphasized that insect resistance in plants is partly due to their chemical constituents (Beck, 1965; Hsiao, 1969 and Maxwell, 1972). Varietal resistance to leafhoppers and planthoppers appears to be primarily biochemical in nature, which exerts both non- preference and antibiosis effects (IRRI, 1975). At present, there is o evidence that the tolerance of the plants to insect attacks is influenced by any chemical (Pathak and Dale, 1983).

Sogawa and Pathak (1970) investigated the causes of *N. Lugens* resistance in the rice variety mudgo and indicated that the sugar content of susceptible and resistant plants was not significantly different but resistant plants contained smaller quantities of amino acids, particularly of aspargine. Pablo (1977) correlated *S. furcifera* resistance with the nutritive value of host plant and indicated that the total sugar in all resistant varieties except IR 2035-117-3, was higher than the susceptible TN 1 and resistant varieties contained lower quantity of amino acids than the susceptible TN 1. Based on these observations, it was reported that the plants containing a high ratio of sugar to amino nitrogen were susceptible. In a separate study, Gunathilagaraj (1983) also reported that resistant varieties contained more sugars and less amino acids. Contrary to these findings, Lal (1988) found that the difference in sugar content gave no indication for the basis of resistance. Similarly amino nitrogen content of plant did not reflect in varietal resistance (Lal, 1988).

The phenolic content of *S. furcifera* resistant variety Colombo was higher than the susceptible TN 1. However, the role of phenolics in resistance of ice varieties to *S. furcifera* was not ascertained (Pablo, 1977 and Lal, 1988) found the role of phenols in variety resistance as resistant varieties contained more phenols.

In preliminary studies on the role of silica levels in resistance to *S. fucifera*, Kim and Heinriches (1982) found that seedlings of resistant variety N 22 grown in a culture solution of silica (SiO_2) adversely affected the development ad survival. Currently, the role of allele-chemicals from resistant riches in imparting resistance to *S. furcifera* are being investigated and Khan and Saxena (1986) indicated that odoriferous and volatile chemicals had a profound on the behaviours and biology.

Breeding for resistance:

The identification of different resistance genes is valuable for systematic incorporation of resistance to *S. furcifera* into improved breeding lines. N 22, with a monogenic dominant resistance gene, was crossed with IR 36 and IR 38 at IRRI, and two back-crosses were made using IR 36 and IR 38 as recurrent parents (Khush, 1980). IR 2035-117-3 with a digenic, dominant resistance gene, was used in multiple crosses to incorporate resistant to *S. furcifera* and several breeding lines with multiple resistance and other important traits have been developed. Both Wbph 1 and Wbph 2 genes have been incorporated into different breeding lines (Angels *et al*., 1981). Efforts are also being made to incorporate Wbph 3, Wbph 4 and Wbph 5 genes into improved plant type background (Khush *et al*., 1982 and Khan and Saxena, 1986).

With increasing importance of the rice leafhopper and planthopper pest complex in recent years, there is a greater need to develop varieties with multiple resistance.

Inheritance of resistance :

Inheritance of rice resistance to *S. furcifera* was first investigated by Sidhu *et al.* (1979). It was found that a single dominant conferred resistance against the pest. This gene was designated wbph 1. Angeles *et al.* (1981) analysed 12 more resistant varieties for resistance. Another single dominant gene that conferred resistance in variety ARC 10239, segregated independently of wbph 1 and was designated wbph 2. In a separate study, Heranandez and Khush (1981) identified a single dominant gene wbph 3 in variety ADR 52 and single recessive gene wbph 4 in variety Podiwi A 8. Genetic analysis of several rice varieties at IRRI recently N Diang Marie (IRRI, 1984). Studies conducted on the mode of inheritance revealed that in addition to major imparting resistance to *S. furcifera* in some rice varieties (IRRI, 1983).

In India, Krishna and Sashu (1980) investigated inheritance of resistance in 5 varieties at AICRIP, Hyderabad. A single dominant gene was found to convey resistance in PTB 33, ARC 14636 and ARC 14766 a single recessive gene was found to govern resistance in ARC 6650 and ARC 14394 (Krishna and Sashu, 1980 and Krishna *et al*., 1984). In a separate study, Mitra and Bentur (1981) reported that IET 6288, a cross of ptb 18/ptb 21/ IR 8, had a pair of dominant genes for governing *S. furcifera* resistance. Gunathilagaraj and Chelliah (1984) studied the genetics of *S. furcifera* resistance in IET 5741 by crossing it with IR 36, a *S. furcifera* susceptible variety and found that the resistance was conditional by a single dominant gene.

At Pantnagar, Singh *et al.* (1984) investigated the inheritance of resistance in two varieties *viz.*, Balmawee and ARC 10464 by crossing them with susceptible TN 1 and indicated that resistance in each of these two varieties was governed by a single recessive gene. In a separate study, Singh *et al.* (1986) studied the genetics of resistance to *S. furcifera* in 10 resistant varieties *viz.*, ARC 5838, ARC 6579, ARC 6624, ARC 10464, ARC 11321, ARC 11324, Balmawee, IET

6288, IR 2415-90-4-3 and Ptb 19 and observed monogenic nature of resistance. Dominant nature of inheritance was found in LET 6288 and Ptb 19 and recessive in ARC 11321, ARC 11324, Balmawee and IR 2415-90-40-3.

In addition to major and minor genes for resistance, a number of rice varieties possess diagenic resistance to *S. furcifera*. Angeles *et al.* (1981) observed that the genes Wbph 1 and Wbph 2 govern resistance in IR 2035-117-3 and Wbph 1 in 368. In addition, the variety Colombo was found to possess Wbph 2 and another recessive gene.

Differential reactions :

There are no confirmed reports of the occurrence of biotypes of *S. furcifera*. However, it is suspected *S. furcifera* populations in India and in Philipines are different biotypes. For instance, out of 118 rice varieties evaluated for resistance at AICRIP, Hyderabad and at IIRI, Philippines, 49 showed different reactions at the two sites. Out of 49 differentials 9 were resistant at IRRI but susceptible at IRRI, 40 were resistant at IRRI but susceptible at Hyderabad, indicating that *S. furcifera* in India and that in the Philippines may be different (IRRI, 1978). In a separate test, N 22 with Wbph 1 resistance gene has been found susceptible at Pantnagar, indicating that the insect populations in India and in the Philipines may belong to different biotypes (Lal, 1981, 1988 and Lal *et al.*, 1988). There have also been reports of differential reactions of resistant varieties to *S. furcifera* populations in South and South-East Asia (Heinriches *et al.*, 1986 and Karim and Razzaque, 1989).

Multilocational tests for evaluation of resistance to *S. furcifera* have also shown differential reactions at test locations in India (AICRIP, 1981, 1982, 1983, DRR, 1984, 1985, 1986). Preliminary studies conducted at IRRI have indicated that biotype selection may occur in general population of *S. furcifera* exposed to resistant varieties for several generations (Heinrichs and Rapusas, 1983). The relationship between resistance level in rice varieties with diverse resistance genes and the rate of biotype selection was investigated. An increase in the virulence of a greenhouse populations of *S. furcifera* feeding on resistant varieties was reported (IRRI, 1980). Although there are no reports on the occurrence of *S. furcifera* biotypes at present, the possibility increases as more highly resistant varieties with varying genetic background is critical to screening programme. Further, it is important to utilize varieties of breeding which have adequate levels of resistance to the population existing in the areas.

REFERENCES

AICRIP (1979). India, Ministry of Agriculture, ICAR and Cooperative Agencies. AICRIP: *Progress Report, Kharif*, **3**(1-3): 95.

AICRIP (1980). India, Ministry of Agriculture, ICAR and Co-operative Agencies. AICIRP: *Progress Report, Kharif*. pp. **3**(1-3): 98.

AICRIP (1981). India, Ministry of Agriculture, ICAR and Co-operative Agencies. AICRIP: *Progress Report, Kharif*, **3**(1-3): 97.

AICRIP (1982). India, Ministry of Agriculture, ICAR and Co-operative Agencies, AICRIP: *Progress Report, Kharif*. **3**(1-3): 106.

AICRIP (1983). India, Ministry of Agriculture, ICAR and Co-operative Agencies, AICRIP: *Progress Report, Kharif*. **3**(1-3): 103.

Angeles, E.R., Khush, G.S. and Heinriches, E.A. (1981). New genes for resistance to White backed planthopper in rice. *Crop Sci*., **21**: 47-50.

Athawal, D.S., Pathak, M.D., Bacalangco, F.N. and Pura, C.D. (1971). Genetics of resistance to brown planthopper and green leaf hopper in *Oryza sativa* L. *Crop Sci.* **11**: 747-750.

Atwal, A.S., Choudhary, J.P. and Sohi, B.S. (1967). Studies on the biology and control of *Sogatella furcifera* Horv. (Delphacidae :Homoptera) in Punjab. *J. Res. Punjab Agric. Univ*., **4**(4): 547-555.

Auclair, J.L. and Baldos, E. (1982). Feeding by the white backed planthopper, *SogatellaFurcifera* within susceptible and resistant rice varieties.*Ent. Exp. Appl*., pp. 200-203.

Beck, S.D. (1965). Resistance of plants to insects. *Ann. Rev. Ent*., **10**: 207-232.

Budianto, E., Kamal, T.I.K., Matsui, M. and Okada, M. (1986). Differences of susceptibility in rice varieties to the white backed planthopper, *Sogatella furcifera* Hovrath (Homoptera: Delphacidae). *Appl. Entomol: Zool*., **21**(4): 629-631.

Choi, S.Y. (1971). Studies on the resistance of the cross lines and some varieties of ice to three hoppers at IRRI in Philipines. *Korean J. Plant Protect.*, **10**(2): 121-125.

Choi, S.Y., Lee, S.W., Chug, B.K. and Kim, J.W. (1982). Varietal resistance of Korean new rice cultivars to the white backed planthopper, *Sogatella furcifera* (Hovrath)III. Seo National University, *College of Agric. Bull*., **7**: 125-128.

Choi, S.Y., Song, Y.H., Lee, J.O. and Park, J.S. (1973). Studies on the varietal resistance of Rice to the white backed planthoper, *Sogatella furcifera* Hovrath. *Korean J. Plant Protect.*, **12**(4): 139-142.

Dhaliwal, G.S., Kumar, I. and Saini, S.S. (1979). Screening of some fine gained rice varieties for resistance to white backed planthopper, *Sogatella furcifera* Hovrath. *Pestol.*, **3**(9): 23-24.

Dhaliwal, G.S., Singh, J., Sidhu, G.S. and Mahli, S.S. (1984). Reaction of promising rice Cultures to white backed planthopper, *Sogatella furcifera* Hovrath. *J. Res. Punjab Agric. Univ*., **21**(4): 631-634.

DRR (1984). India, Ministry of Agriculture, ICAR and Co-operative Agencies. DRR, *Progress Report Kharif*, pp. **3**.62-3.126.

DRR (1985). India, Ministry of Agriculture, ICAR and Co-operative Agencies. DRR, *Progress Report Kharif*. pp. **2**(1-2): 108.

DRR (1986). India, Ministry of Agriculture, ICAR and Co-operative Agencies. DRR, *Progress Report Kharif*. pp. **2**(1-2): 125.

DRR (1987). India, Ministry of Agriculture, ICAR and Co-operative Agencies. DRR, *Progress Report Kharif*. pp. **3**(1-2): 127.

DRR (1988). India, Ministry of Agriculture, ICAR and Co-operative Agencies. DRR, *Progress Report Kharif*. pp. **2**(1-2): 128.

Gunathilagaraj, K. (1983). Ecology and host resistance of white backed planthopper, *Sogatella furcifera* (Hovrath) in rice. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, T.N. (INDIA).

Gunathilagaraj, K. and Chelliah, S. (1984). Varietal resistance of rice to white backed Planthopper (WBPH). *Intl. rice Res. Newsl*., **9**(5): 8.

Gunathilagaraj, K. and Chelliah, S. (1985a). Components of resistance to the white backed Planthopper, *Sogatella furcifera* (Hovath) in some rice varieties. *Tropical Pest Mgmt*., **31**(1): 38-46.

Gunathilagaraj, K. and Chelliah , S. (1985c). Feeding behaviour of whitebacked planthopper, *Sogatella furcifera* (Hovrath) on resistant and susceptible rice varieties. *Crop. Prot*., **4**(2): 255-262.

Gupta, A.K. and Shukla, K.K. (1985). Sources and inheritance to whitebacked planthopper, *Sogatella furcifera* in rice. Paper presented in Intl. rice Genetics Symposium, May 27-31,1985, IRRI, Philipines.

Heinrichs, E.A. and Kalode, M.B. (1985). New techniques for screening ice cultivars for Resistance to insects. Intl. rice research Conference, June 1-5, IRRI, Philipines.

Heinrichs, E.A., Medrano, F.G.,Rapusas, H.R.,Vega, C., Medina, E., Romena, A., Viajante, V.,Sunio, L.,Domingo, I. and Camanag, E. (1985). Insect pest resistance of IR-5-IR 62.*Intl. Rice Res. Newsl*., **10**(6): 12-13.

Heinrichs, E.A., Medrano, F.G., Sunio, L., Rapusas, H.R., Romena, A., Vega, C., Viajante, V., Centina, D. and Domingo, I. (1982). Resistance of IR varieties to insect pests. *Rice Res. Newsl*., **7**(3): 9-10.

Heinrichs, E.A. and Rapusas, H.R. (1983). Levels of resistance to the whitebacked planthopper *Sogatella furcifera* (Hovrath) (Homoptera: Delphacidae) in rice vaieties with the same major resistance genes. *Environ. Entomol.*, **14**: 83-86.

Heinrichs, E.A., Rapusas, H.R., Khush, G.S., Chelliah, S., Gunathilagaraj, K., Akib, W.S., Choi, S.Y.,Pongprasert, S., Katanyukul, W., Huynh, N.V. and Tien, T.H. (1986). Virulence of whitebacked planthopper (WBPH) populations in South and South- East Asia. Report of a collaborative project. *Intl. Rice Res. Newsl.*, pp. 12-13.

Hernandez, J.E. and Khush, G.S. (1981). Genetics of resistance to whitebacked planthopper in some rice (*Oryza sativa* L.) varieties. *Oryza*., **18**.44-50.

Horbor, E. (1972). Plant resistance to insects. Agric. Sci. Co-op. State Res. Serv. U.S. Department of Agriculture, 10 pp.

Hsiao, T.H. (1969). Chemical basis of host selection and plant resistance in oligophagous Insects in : Proc. Second. Intl. Symp. On Insect and Host lant, Wageningen, pp. 777-778.

IRRI (1971). Annual Report for 1970. International Rice Research Institute, Los Banos, Philipines.

IRRI (1972). Annual Report for 1971. International Rice Research Institute, Los Banos, Philipines.

IRRI (1973). Annual Report for 1972. International Rice Research Institute, Los Banos, Philipines.

IRRI (1975). Annual Report for 1974. International Rice Research Institute, Los Banos, Philipines.

IRRI (1976). Annual Report for 1975. International Rice Research Institute, Los Banos, Philipines.

IRRI (1977). Annual Report for 1976. International Rice Research Institute, Los Banos, Philipines.

IRRI (1978). Annual Report for 1977. International Rice Research Institute, Los Banos, Philipines.

IRRI (1980). Annual Report for 1979. International Rice Research Institute, Los Banos, Philipines.

IRRI (1981). Annual Report for 1980. International Rice Research Institute, Los Banos, Philipines.

IRRI (1982). Annual Report for 1981. International Rice Research Institute, Los Banos, Philipines.

IRRI (1983). Annual Report for 1982. International Rice Research Institute, Los Banos, Philipines.

IRRI (1984). Annual Report for 1983. International Rice Research Institute, Los Banos, Philipines.

IRRI (1985). Annual Report for 1984. International Rice Research Institute, Los Banos, Philipines.

IRRI (1986). Annual Report for 1985. International Rice Research Institute, Los Banos, Philipines.

Kalode, M.B., Kirshna ,T.S., Pophaly D.J. and Lakshrinarayana, A. (1977). Note on new donors having multiple resistance to major insect pests of rice. *Indian J. Agric. Sci.*, **47** : 626-627.

Karim, A.N.M.R. and Razzaque Q.M.A. (1989). Rice resistance to whitebacked planthopper (WBPH) *Sogatella furcifera* in Bangladesh. *Intel.Rice. Newsl.*, **14**(2): 16-17.

Kartohard, Jono A. and Suwito, T. (1984). Screening rice varieties for resistance to whitebacked Planthopper, *Sogatela furcifera. Intel. Rice. Newsl*., **9**(2): 6-7.

Kaul, S.K. (1985). Sources of resistance to whitebacked planthopper, Sogatella furcifers (Horvath) in rice M.Sc. (Ag.) Thesis. Deptt. of Entomology, G.B.P.U.A. & T., Pantnagar, U.A. (INDIA).

Khan, Z.R. and Saxena, R.C. (1984a). Electronic device to record feeding behavior of whitebacked Planthopper on susceptible and resistant rice varieties. *Intal. Rice. News.*, **9**(1): 8-9.

Khan, Z.R. and Saxena, R.C. (1984b). Electronically record waveforms associated with the feeding behaviour of *Sogatell furcifera* (homoptera: delphacidae) on susceptible and resistant rice varieties, *J. Econ. Entomol*., **77**(6): 1479-1482.

Khan, Z.R. and Saxena, R.C. (1985). Behavioural and physiological responses of *Sogatella furcifera* (homoptera: Delphacidae) to selected resistant and susceptible rice cultivars. *J. Econ. Entomol*., **78**(6): 1280-1286.

Khan, Z.R. and Saxena, R.C. (1986). Varietal resistance in rice against *Sogatella furcifera* (Horvath). *Crop. Prot*., **5**(1): 15-25.

Khatri, A.K. and Patel, R.K. (1976). Varietal susceptibility of rice to whitebacked planthopper, *Sogatella Furcifera* Horv. (Delphaccidae: Hemiptera). *JNKVV Res. J*., **10**(1)(suppl): 78-79.

Khush, G.S. (1980). Breeding rice for multiple disease and insect resistance. In: Rice improvement in China and other Asian countries, International Rice Research Institute and Chinese Academy of Agriculture Sciences, IRRI, los Banos, Philippines. 307 p.

Kush, G.S. and Choudhary, R.C. (1981). Role of resistant varieties in integrated past management of rice. *Food Fert. Tech. Centre Extn. Bull*., **162**: 1-13.

Khush, G.S., Seshu, D.V. and Verma, S.K. (1982). Varietal resistance to ehitebacked planthopper. Paper Presented at the International Rice Research Conference, April 19-23, 1982, Los Banos, Philipines, (Minreographed).

Kim, Hong-Sun and Heinrichs, E.A. (1982). Effect of silica level on whitebacked planthopper. *Intl. Rice. Res. Newsl.,* **7**(4): 17.

Kim, Y.H., Lee, J.O. and Goh, H.G. (1982). Differences between seedling bulk and population buildup tests of varietal resistance to whitebacked Planthopper. *Intl. Rice Res. Newsl*., **7**(5): 11.

Kittur, S.V. and Patel, R.K. (1968). Varietal screening for paddy pests. Annual /report, Central Rice Research Station. Raipur, M.P., (INDIA).

Krishna, T.S. and Sashu, D.V. (1980). Genetics of whitebacked planthopper resistance. *Intl. Rice Res. Newsl*., **5**(2): 6.

Krishna, T.S., Sashu, D.V. and Kalode, M.B. (1980). Multiple pest resistance in some tall traditional Varieties. *Intl Rice Res. Newsl.,* **1.5**(3): 8-9.

Krishna, T.S., Sashu, D.V. and Kalode, M.B. (1984). Inheritance of resistance to whitebacked Planthopper in rice. *Indian J. Ent. Plant Breed.,* **44**(2): 329-335.

Kushwaha, K.S., Mrig, K.K. and Singh, R. (1982a). whitebacked planthopper population in rice cultivars. *Internat. Rice Res. Newsl*., **17**(2): 8.

Kushwaha, K.S., Mrig, K.K. and Singh, R. (1982b). Damage to rice cultivars by whitebacked planthopper. *Indian J. Ent.,* **44**(3): 283-284.

Kushwaha, K.S., Mrig, K.K. and Singh, R. (1986). Field evaluation of rices for whitebacked planthopper (WBPH) and leaffolder (LF) resistance. *Intl. Rice Res. Newsl*., **11**(1): 8-9.

Lal, M.N. (1981). Varietal resistance to whitebacked planthopper, *Sogatella furcifera* (Hovrath) in rice. M.Sc. (Ag.) Thesis. Department of Entomology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.K. (INDIA).

Lal, M.N. (1988). Evaluation of rice varieties for resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath). Ph.D. Thesis, Department of Entomology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.K. (INDIA). 190 pp.

Lal, M.N., Verma, S.K., Pathak, P.K. and Sachan, G.C. (1988). Growth and development indices of *Sogatella furcifera* (Horvath) on some resistant and susceptible rice varieties. *Agric. Sci. Digest.* **8**(2): 91-93.

Lal, M.N., Verma, S.K., Sachan, G.C., Pathak, P.K. and Nands, J.S. (1983). Varietal resistance to Whitebacked planthopper. *Intl. Rice Res. Newsl*., **11**(1): 8-9.

Lee, J.O. and Park, J.S. (1976). Studies on varietal resistance of rice to the plant and leafhoppers. Korean Office of Rural Development Project Report. **18**: 67-72.

Maxwell, F.G. (1972). Host plant resistance to insect nutritional and pest management relationship. In : Insects and mite nutrition (ed. J.G. Rodriguze). Amsterdom: north Holland. pp. 509-602.

Misra, D.S., Reddy, K.D. and Misra, B.C. (1986). Varietal screening for leafhopper and planthopper resistance at Varanasi, India, *Intl. Rice Res. Newsl*., **11**(1): 9-10.

Mitra, G.N. and Bentur, J.S. (1981). Rice resistance to whitebacked planthopper. *Intl. Rice Res. Newsl*., **6**(1): 8.

Miyake, T. and Fujiwara, A. (1961). Studies on host plant preference in the whitebacked planthopper *Sogatella furcifera* Horvath. *Jap. J. Appl. Entomol. Zool.,* **5** : 174-179.

Nair, R.V., Masajo, T.N. and Khush, G.S. (1982). Genetic analysis of resistance to whitebacked planthopper in twenty one varieties of rice, *Oryza sativa* L. *Theor. Appl. Genet*., **61**: 19-22.

Pablo, S.J. (1977). Resistance to whitebacked planthoper *Sogatella furcifera* (Horvath) in rice varieties. Ph.D. Thesis. Indian Agriculture Research Institute, New Delhi, (INDIA).

Painter, R.H. (1951). *Insect resistance in crop plants*. The MacMillan Co., New York, 520 pp.

Panda, N, and Heinrichs, E.A. (1983). Levels of tolerance and antibiosis in rice varieties having moderate resistance to the brown planthopper, *Nilaparvata lugens* (stal) Hemiptera: Delphacidae. *Environ. Entomol*., **12**: 1204-1214.

Pathak, M.D. (1977). Defense of the rice crop against pests. In: Day, P. R. (Ed.). The genetic basis of epidemics in agriculture. *Ann.N. Y. Acad. Sci.,* **287** : 287–295.

Pathak, M.D. and Dale, D. (1983). Biochemical basis of resistance in host plants to insect pests, pp. 56–72. In L. W. Schemitt [Eds.], Chemistry and world supplies. Pergamon Press, Oxford, NEW YORK, U.S.A.

Pathak, M.D. and Heinrichs, E.A.(1982). A bibliography of varietal resistance to the rice gall midge, *Orseolia oryzae* (Wood-Mason) Commonwealth institute of Entomology, LONDAN, UNITED KINGDOM.

Pathak, P.K., Verma, S.K. and Lal, M.N. (1986). Research of rice varieties to whitebacked planthopper (WBPH). *Intl. Rice Res. Newsl.*, **11**(3): 7.

Ramaraju, K, Sundara Babu, P.C. and Gunathilagaraj, K. (1989). Whitebacked planthopper (EBPH) *Sogatella furcifera* (Horvath) survival and nymph emergence on some rice varieties. *Intl. Rice Res. Newsl.,* **14**(6): 9.

Rapusas, H.R. and Heinrichs, E.A. (1985). Whitebacked Planthopper (WBPH) growth and development on rice with monogenic or dysgenic resistance. *Intl. Rice Res. Newsl.*, **10**(5): 9-10.

Reddy, A.A., Bentur, J.S. and Kalode, M.B. (1985). Relative performance of selected rice varieties in glasshouse and field screening against whitebacked planthopper, *Sogatella furcifera* Horvath. *Indian J. Plant Prot*., **13**(1): 47-48.

Rodriguze-Rivera, R. (1972). Resistance to the whitebacked Planthopper, *Sogatella furcifera* (Horvath)in rice varieties. M.S. Thesis, University of Philipines, Los Banos, Philipines. 69 pp.

Romena, A.M., Rapusas, H.R. and Heinrichs, E.A. (1986). Evaluation of rice accessions for resistance to the whitebacked planthopper, *Sogatella furcifera* (Horvath)(Homoptera : Delphacidae). *Crop Prot.,* **5**(5): 334- 340.

Saini, R.S., Khush, G.S. and Heinrichs, E.A. (1982). Genetic analysis of resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath), in some rice varieties. *Crop Prot.,* **1**: 289-297.

Saxena, K.N. (1969). Patterns of insect plant relationships determining susceptibility or resistance of different plant to an insect. *epidemics. Exp. Appl.*, **17**: 751-766.

Saxena, R.C. and Pathak, M.D. (1977). Factors affecting resistance of rice varieties to brown planthopper *Nilaparvata lugens* (stal.). In proceedings of the 8th annual conference of the pest cantrol council of the Philippines Bacolod city.

Sidhu, G.S., Khush, G.S., Medrano, F.G. (1979). A dominant gene in rice for resistance to white-backed planthopper and its relationship to other plant characteristecs. *Euphytica*, **28**: 227-232.

Singh, J., Mahli, S.S., Sidhu, G.S. and Singh, D.P. (1984a). Screening of advanced rice cultures against white backed planthopper and rice leafhopper. *J. Res. Punjab. Agric. Univ.,* **21**(3): 329-333.

Singh, L.J., Tiwari, D.N. and Singh, H.N. (1986). Evidence for genetic control of herbicide resistance in a rice field isolate of *Gloeocapsa* sp. capable of aerobic diazotrophy under photo autotrophic conditions. *J. General Appl. Microbiol.*, **32** : 81-88.

Sogawa, K. and Pathak, M.D. (1970). Mechanisms of brown planthopper resistance in Mudgo variety of rice (Hemiptera: Delphacidae). *Appl. Entomol. Zool.*, **5** : 145–158.

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

Verma, S.K., Pathak, P.K., Singh, B.N. and Lal, M.N. (1979). Indian biotypes of the brown planthopper. Internat. *Rise Res. Newsl,* **4** : 7.

7th Year
★★★★★ of Excellence ★★★★★