“BROWN PLANTHOPPER, *Nilaparvata lugens* (Stal.) DONORS VALIDATION TEST ON EVALUATED RICE GENOTYPES”

M. Sc. (Ag.) THESIS

By

SERVEN KUMAR VERMA

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.)

2013

“BROWN PLANTHOPPER, *Nilaparvata lugens* (Stal.) DONORS VALIDATION TEST ON EVALUATED RICE GENOTYPES”

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

SERVEN KUMAR VERMA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

Master of Science

In

Agriculture
(ENTOMOLOGY)

ROLL NO. 15324 **ID NO.110305028**

JULY, 2013

CERTIFICATE – I

This is to certify that the thesis entitled **"BROWN PLANTHOPPER, *Nilaparvata lugens* (Stal.) DONORS VALIDATION TEST ON EVALUATED RICE GENOTYPES"** Submitted in partial fulfilment of the requirements for the degree of **"Master of Science in Agriculture"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, (Chhattisgarh) is a record of the bonafide research work carried out by **SERVEN KUMAR VERMA** under my guidance and supervision. The subject of the thesis has been approved by student's advisory committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

Date:

Chairman
Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	: Dr.D.K.Rana	____________
Member	: Dr.Shiv.K.Shrivastava	____________
Member	: Dr.V.K.Dubey	____________
Member	: Dr.A.K.Sarawagi	____________
Member	: Dr. R. R. Saxena	____________

CERTIFICATE – II

This is to certify that the thesis entitled **"BROWN PLANTHOPPER, *Nilaparvata lugens* (Stal.) DONORS VALIDATION TEST ON EVALUATED RICE GENOTYPES"** submitted by **SERVEN KUMAR VERMA** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Entomology** has been approved by the External Examiner and Student's Advisory Committee after oral examination.

(Dr. H. S. Singh)

Date: 29/11/13 **EXTERNAL EXAMINER**

Major Advisor ______________________

Head of the Department ______________________

Dean/ Dean Faculty ______________________

Director of Instructions ______________________

ACKNOWLEDGEMENT

First of all I would like to thank and praise Almighty "God" the most beneficent and merciful, for all his love and blessing conferred upon mankind.

I take this golden opportunity to express my deepest sense of gratitude to the Chairman of my Advisory Committee Dr. D.K. Rana, Professor, Department of Entomology, for his research insight, valuable guidance, constant encouragement, unique supervision and kind sympathetic attitude, despite his heaviest schedule of work, his helpful, patience, creative guidance has given touch of excellence to this manuscript.

With extreme pleasure, I extent my heartiest thanks to the members of my Advisory Committee Dr. S.K. Shrivatava, Principle Scientist, Department of Entomology, Dr. V.K. Dubey, Professor, Department of Entomology, Dr. A.K. Sarawagi, Professor, Department of Genetics and Plant Breeding, Dr. R.R. Saxena, Asso. Professor, Department of Agril. Statistics, Mathematics and Computer Science for their excellent guidance, suggestions and regular encouragement during the course of investigation.

I express my sincere and profound gratitude to Dr. V.K. Kosta, Prof. and Head, Department of Entomology for his inspiring suggestions and providing me all the necessary facilities, during my study.

I wish to record my sincere thanks to Dr. S. K. Patil, Hon'ble Vice Chancellor, Dr.O.P. Kashyap, Dean, College of Agriculture, Raipur, Dr. S. Patel, Director of Instructions and Dr. D.A. Sarnaik, Director Research Services, IGKV, Raipur for their administrative and technical help which facilitated my research work.

I am highly indebted to the teachers of my Department Dr. A.K. Dubey, Dr. Rajeev Gupta, Dr. V.K. Koshta, Dr. (Smt.) Jaya Laxmi Ganguli, Dr. R.N. Ganguli, Dr. H.K. Chandrakar Dr. Y.K. Yadu, Dr. Sanjay Sharma, Shri A.K. Gupta, Shri Vikas Singh and Shri Navneet Rana for their constant co-operation, suggestion, encouragement and help during my investigation.

I do express my heartiest thanks to Shri R.S. Yadav, Shri D.N. Chandrakar, Shri Kunjulal Sahu, Shri Hemchand Nayak, Shri Sankirtan, Shri Mahadev, non teaching staff of our department who were always ready to help me during the period of study.

I will be failing in my duties if I don't convey my sincere thanks to my seniors Mangesh sir, and Randeep Kushvaha sir, my batchmates, Harsh, Rambihari, Tarun, Manish, Subodh, and Payal my juniors Sanjay, Bhupesh, chandramani, Yashpal, Yuvraj, nithish, Pritansha Latesh and Prity .

I am deeply privileged to express heartfelt thanks to my best friends omprakash, Ghanshyam and Chatrapal who provided me an inner strength and guided me during my entire academic career as to steer up my ambition in a proper way.

For the most important personalities of my life, there aren't enough words to express my gratitude to My parents Mr. L.P. Verma and Smt. Puspa verma , My sister Anju verma and my brother Satish verma for their constant encouragement, sincere prayers, expectations and blessings which have always been the most vital source of inspiration and motivation in my life.

I would like to convey my cordial thanks to all those unmentioned persons who helped me directly and indirectly to fulfill my dream come true.

Department of Entomology,
College of Agriculture,
IGKV, Raipur (C. G.)

(Serven Kumar Verma)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
%	Per cent
@	At the rate of
BPH	Brown planthopper
^0C	Degree Celsius
CD	Critical difference
cm	Centimeter
DOP	Days old plant
et al.	And other
Fig.	Figure
g	Gram
ha	Hectare
hrs	Hours
i.e.	That is
kg	Kilogram
m ha	Million hectare
mm	Millimeter
mt	Metric tonne
No.	Number
PHS	Planthopper screening
SEm	Standard error of mean
Sr.No.	Serial Number
viz.	Namely

Introduction

CHAPTER- I

INTRODUCTION

Rice (*Oryza sativa* L.) is a plant belonging to the family of grasses, Gramineae or Poaceae. It is one of the most important food crop of India and 2nd of the world. It is primary staple food source for half of the world's population. It has the distinction of being the most extensively cultivated crop in the world. Among the rice growing countries, India having the largest area under rice in the world and in case of production it is next to china. However, productivity of India is much lower than of Egypt, Japan, China and Vietnam, USA and Indonesia and also with the average productivity of the world. It contributes 42 % of the total food grains production and 45% of the total cereal production in the country. About 90 per cent of world rice is produced and consumed in Asia. Over 75 per cent of the world supply is consumed by people in Asian countries and thus rice is of immense importance to food security of Asia. Rice occupies prime position in agriculture scenario.

Rice is the staple food for over 65% of Indian population. It is under diverse climatic conditions over a wide geographic range. It is comparatively more adoptable crop and is grown throughout South East Asian countries. In India rice is grown on an area of 44.3 m ha in different agro-climatic region with a production of 89.09 mt during 2010-2011 (Anonymous, 2011).

Rice is an ancient crop and is classified as one of the most economically important cereal foods. It is the staple food for many people around the world especially in Asia where half of the world's population live. As an energy source, rice mainly provides carbohydrates and some proteins, vitamins and fibers for human consumption. In 2007, the Food and Agriculture Organization (FAO) estimated the production areas approximately reached 156 x 106 hectares with 660 x 106 tons yield (Tester and Langridge, 2010).

Rice is the leading food crop for humans, providing dietary energy and protein for half of the world's population especially in the Asian region. Total rice production however, is expected to face serious challenges and is likely to be more unstable in the near future. A world food crisis happened in 2007- 2008 and this caused the price of food in international markets to increase drastically (Timmer, 2010). In addition, it has been predicted that the world population in 2020 will increase 29.7% to 7,593 billion people (Mullins, 1999), which could cause a huge demand for this crop. Therefore, it will be necessary for annual rice production to double to keep up with worldwide demand.

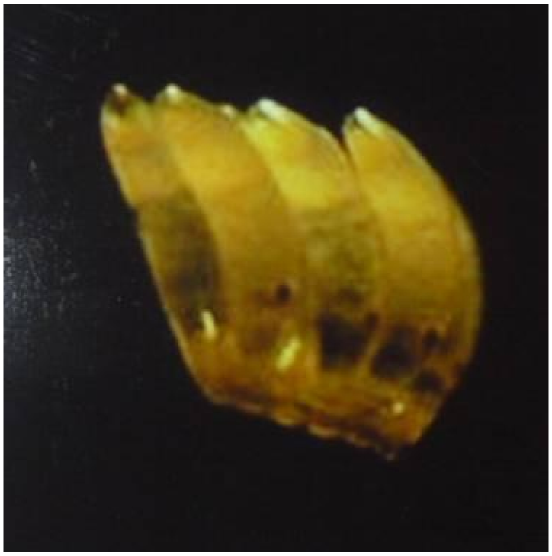
This crop also plays an important socio-economic role providing the rural population with many job opportunities. According to the FAO of the UN in 2010, China, India, Indonesia, Bangladesh, Vietnam and Thailand were among the top list of world rice production countries (Alexandratos *et al.*, 2006), but only a few from those countries participated in the export market. This can create problems such as those encountered recently. The demand for rice has increased sharply in the international market followed closely by the price. This phenomenon has resulted in global social problems because most people especially in developing countries cannot afford to buy rice. With the world's population increasing each year, immediate action needs to be undertaken to make sure the production of rice can meet future demand, which is projected to increase to 771.1 mt in 2030 (Nguyen and Ferrero, 2006).

The Chhattisgarh state is popularly known as "rice bowl" as rice is the major crop of the state. Presently the area under rice cultivation in Chhattisgarh is about 3.61 million hectare, which is 26 per cent of the total cultivable land. The total production of rice in the state is 5.48 mt with an average productivity of 15.17 q / ha (Anonymous, 2010). It is situated in the tropical interior belt of India. Climate of Chhattisgarh in general is sub humid type with an average rainfall of about 1400 mm.

The brown planthopper (BPH) *Nilaparvata lugens* (Stal.) (Hemiptera: Delphacidae) is a typical sucking pest of rice, which feeds on phloem sap and thus affects the growth of rice and results in 'hopperburn' in rice fields (Watanabe & Kitagawa, 2000). The different life stages are shown in Plate 1. The brown planthopper (BPH) causes direct damage to rice plant by sucking the plant sap. In addition to the feeding damage, it is also transmits grassy stunt (Rivera *et al*., 1966), ragged stunt (Ling *et al*., 1978) and wilted stunt viral disease of rice (Chen and Cheng, 1978), which are serious diseases in the tropical region (Du, 2007). The injury of brown planthopper caused a reduction in rice plant height if infestation took place before the reproductive stage. In Chhattisgarh, this insect has assumed greater importance due to its severe outbreak in 1975 and consequent yield losses reported to the extent of 34.3 per cent (Gangrade *et al*., 1978).

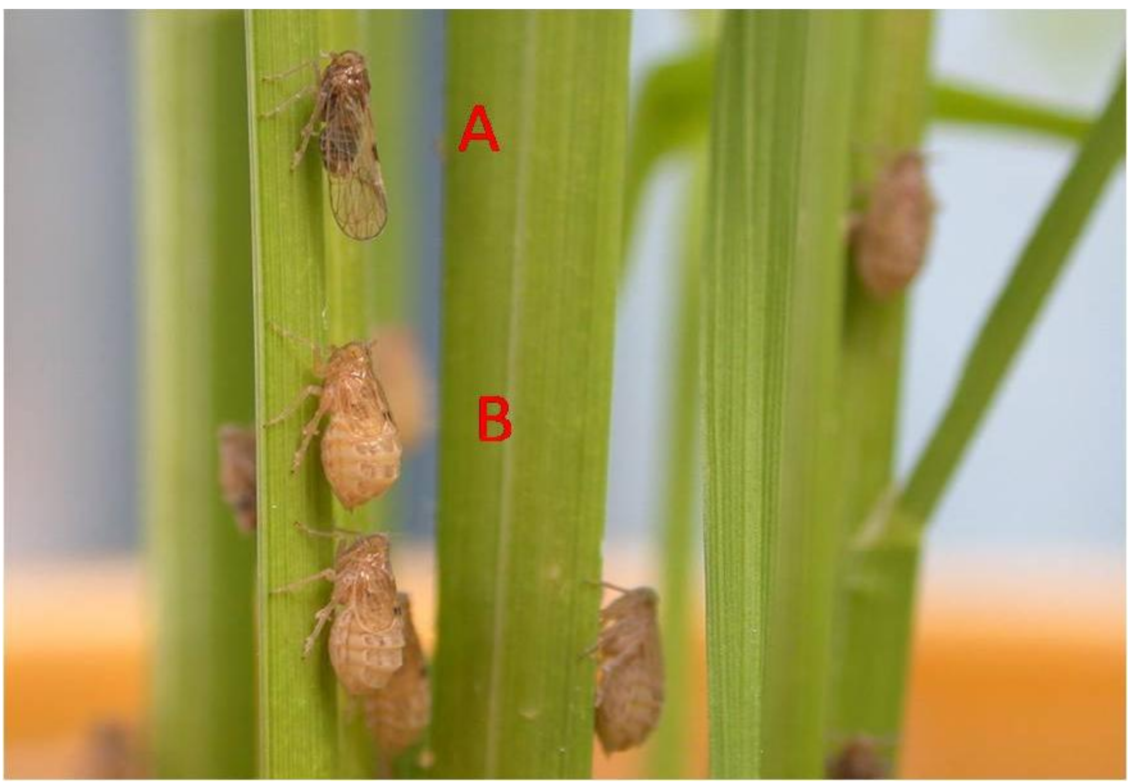
The colour of BPH varies from yellowish brown to dark brown. Length of macropterous male ranges 2.3 to 2.4 mm (3.8 to 4.2 mm, including fore wing), female ranges 2.8 to 3.2 mm (4.4 to 4.8 mm, including fore wing), brachyterous male ranges 2.0 to 3.1 mm, female ranges 2.7 to 3.5 mm, post-tibial spur with 30-36 teeth (Okada, 1977). Variations of the macropterous form of wings and the spur at the apex of the hind tibia are the characteristic of genus *Nilaparvata.*

BPH is widely distributed in rice growing areas throughout South and Southeast Asia. It is also found in East Asia, like Japan, Korea, China, Taiwan, Philippines, Vietnam, Laos, Thailand, Myanmar, Malaysia, Indonesia, Brunei,



Eggs

Nymphs



A. Adult Male **B. Adult Female**

Plate-1: Different life stages of BPH *Nilaparvata lugens* (Stal.).

Cambodia, Nepal, India, Bangladesh, Bhutan, Shri Lanka, Pakistan, New Guinea, The South Pacific Islands and Australia (Dyck and Thomas, 1979; Khush, 1979)

Brown planthopper (BPH), *Nilaparvata lugens* (Stal.) is a sporadic pest in most of the rice growing tracts of the world. It was one of the most serious insect pest of rice in Japan many year ago (Kisimoto, 1960), but now it is one of the most serious and destructive insect pest of rice in several countries of the world including India. During 1973, In India it was first observed to cause extensive damage to rice crop in Kerala (Nalini kumari and Mammen, 1975). Thereafter, subsequent reports on the incidence of this pest were also received from other main rice growing tracts of the country namely, Andra Pradesh., Bihar, Haryana, Orissa, Punjab, Uttar Pradesh., and Tamilnadu (Kulshreshtha *et al*., 1974).

Brown planthopper (BPH) *Nilaparvata lugens* (Stal.) causes the most serious damage to the rice crop globally among all rice pests. Historically it was minor pest of rice, emerged as a major pest in the tropical Asia during green revolution of the 1960s (Heinrichs and Mochida, 1984). In India, it was first reported in Kerala during 1958. The first severe outbreak occurred in Kerala during 1973-74 damaging about 50000 ha of rice (Bai *et al*., 1992). The severe outbreak of this pest was noticed during 2007 in parts of Cauvery command area in Karnataka and during 2008 in Haryana, Punjab and Delhi (Siddegowda, 2009).

The best example of crop damage from brown planthopper can be taken from Indonesia. From 1977 to 1979, over two million hectares of rice was lost due to brown planthopper damage. Again from 1984 to 1986 brown planthopper outbreaks reduced rice yields nationwide (Whalon *et* al., 1990).

The brown planthopper (BPH) is a major threat to rice production and causes significant yield loss annually. Host-plant resistance is an important strategy to reduce the damage caused by BPH and increase rice productivity. Twenty-one major genes for BPH resistance have been identified by using standard evaluation methods developed at the International Rice Research Institute (IRRI) to distinguish resistance or susceptibility of rice genotypes to BPH biotypes/populations (Jena & SukMan 2010).

Host plant resistance has played an important role in the management of pest successfully during past two decades. Several resistance varieties have been developed and grown in different areas of India (Mathur *et al*., 1999; Krishnaiah *et al*., 1999). As a result it contributed towards the suppression of the pest for nearly last twenty years. Therefore development of varieties with high resistance is a prime requirement. The land races existing in different areas of India provide enough opportunity to select such donors through proper screening against this pest.

In Chhattisgarh, rice is staple food of majority of the population. It is grown in 36 lakh ha area in all the three agro climatic zones of Chhattisgarh *viz*. Chhattisgarh plains, Northern hills and Bastar plateau zone. Brown planthopper is one of the major pest occur in all the three zones. There is a tremendous scope in identification of host plant resistance for BPH resistance.

Looking to the above mentioned fact screening of rice varieties is useful technique for management of this pest and reduce the quantity of insecticide used to control as the major components of an effective pest management strategy against the brown planthopper.

Keeping in this view, the present investigation entitled **"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes."** was conducted in the Glass House, Department of Entomology, College of Agriculture, IGKV, Raipur during the year 2012-13 with the following objectives.

Objectives of investigation

1. Screening of rice genotype for resistant to brown planthopper *Nilaparvata lugens* (Stal.) in glass house condition.
2. Nymphal survival response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.
3. Ovipositional response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.
4. Probing mark test of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.

Review of Literature

CHAPTER- II

REVIEW OF LITERATURE

The studies have been carried out by different scientists on the various aspects of host plant resistance to *Nilaparvata lugens* (Stal.) on rice. For the sake of convenience and clarity the literature pertinent to the present studies was reviewed and included in this chapter.

The brown planthopper, *Nilaparvata lugens* (Stal.) belongs to the family Delphacidae, sub order Homoptera and order Hemiptera.Through out the world 14 determined and 2 undetermined species are reported as the member of genus *Nilaparvata* (Mochida,1977), out of which *Nilaparvata lugens* is recognized as serious pest of rice (Nasu,1964).

The occurrence and evolution of prolific biotypes of brown planthopper is a constant threat to the stability of the pest resistant rice varieties presently under cultivation (Pathak and Saxena, 1980). The term BPH biotype refers to the populations of *Nilaparvata lugens* which differs in their ability to feed on and destroy varieties with a specific major gene for resistance (Diehl and Bush, 1984). At least 5 different biotypes of BPH are known (Anonymous, 1981).

Seven differential donors tested at Raipur with local population of brown planthopper showed variation in reactions as compared to IRRI BPH population. Similarly, twenty one IR varieties exhibited differences when the results were examined against three BPH biotypes at IRRI. Thus concluded that the Raipur BPH population is different from that of at IRRI. Similarly, 15 Pattambi BPH donors also behaved dissimilarly towards Raipur BPH population too less virulent than that of Raipur (Pophaly and Rana, 1994).

2.1 Mass rearing

To study the resistance studies against the brown planthopper, it is essential to get continuous supply of brown planthopper insects. So to meet the primary requirement brown planthopper was mass reared on some selected rice varieties; the brief review of mass rearing is presented as here under.

Brown planthopper, *Nilaparvata lugens* was successfully reared round the year on rice variety Jaya, grown in nutrient solution (Majumdar, 1980). The BPH population of Hyderabad and Pantnagar is maintained separately on 30 to 50 days old potted plants of TN1 variety in glasshouse to prevent any possible mixing. Optimum temperature of 27 ± 3°C and relative humidity of 65 to 85 percent were provided for better multiplication and survival of the insects (Bhattacharyya *et al*., 1983).

The best protocol for mass rearing of brown planthopper was determined in China. Six BPH rearing methods i.e. rice buds (RB), rice seedlings (RS), seedlings soil less culture (SSC), mature rice (MR) and rice stem cultured in nutrient fluid (RSF) were compared. MR and RSF showed good rearing effects but SSC exhibited significant advantages in survival rate of the third to fifth nymphal stage and emergence rate. Rearing of BPH lower than 20-25°C had the best effect but below 20°C the seedlings were unhealthy, SSC is best method for mass rearing of BPH under laboratory conditions (Liu *et al*., 2002).

2.2 Screening of rice genotypes for resistance to brown planthopper (BPH) *Nilaparvata lugens* (Stal.)

India is very rich in plant genetic diversity. Many scientists evaluated rice germplasm material pooled from various sources and tested for resistance against brown planthopper (BPH) insect.

Eight hundred and ninety cultivars from North-East India were screened against brown planthopper, *Nilparvata lugens* (Stal). Sixty nine entries were identified as resistant or moderately resistant. Most of the donors are from hilly districts of Assam, Meghalaya and from East and South Manipur districts. Age of plant appears to have no influence on the resistance reaction of the test varieties identified from mass screening tests (Krishna *et al.*, 1977).

The resistance genes of rice cultivar Abhaya may obtain from two donors, CR-157-392 and OR67-21. The quantitative resistance of rice to BPH usually found in rice cultivar that shows moderately resistance to BPH (Alam and Cohen 1998).

The resistance of 38 elite rice lines to brown planthopper (BPH), *Nilaparvata lugens* was investigated in the laboratory during 2000-01 in China, five elite lines were found to be resistant to BPH (Shen *et al.*, 2002).

At IGKV Raipur, one hundred sixty eight promising rice genotypes were tested against brown planthopper in laboratory conditions. Out of which, 7 rice genotypes were found resistant, 26 as moderately resistant and rest of the genotypes as susceptible to brown planthopper (Urre *et al.*, 2004a).

Soundararajan *et al.* (2004) used the standard seedbox screening test (SSST) to measure the levels of resistance on standard checks, parents and DH lines of the cross IR64/Azucena for resistance to BPH at seedling stage. In this experiment, the damage scoring of Ptb33, TN1, IR 64, Azucena and DHLs were recorded as 3.7 ± 0.7, 8.3 ± 0.7, 5.7 ± 0.7, 9.0 ± 0.0 and 7.1 ± 0.1, respectively.

One hundred twenty one promising rice genotypes were tested against brown planthopper in laboratory conditions at IGKV, Raipur. Out of these 3 rice genotypes were found resistant, 20 as moderately resistant and rest of the genotypes as susceptible to brown planthopper (Bhimrao *et al.*, 2005).

Su *et al.* (2006) carried out screening of rice genotypes along with resistant check Rathu Heenati and susceptible check TN1 and found that Kaharamana was resistant to biotype 1 of BPH with score 1.63, while 02428 was susceptible with score 7.07. They also stated that Kaharamana was less resistant than Rathu Heenati whose resistance score was 0.4.

Siddegowda (2009) reported that over a period of thirteen years (1996-2008), 645 and 2186 entries/cultivars were screened against brown planthopper under Planthopper Screening (PHS) and National Screening Nursery (NSN1) trial, respectively, both in green house and field. The study revealed that 158 donors possessing different levels of resistance to BPH. Rice cultivars IET 7575, IET 8116, IET 8110, IET 9912, IET 9873 and BPT 2217 were identified as resistant varieties, whereas IET 7575 and IET 8116 were released as BPH tolerant varieties for cultivation in Cauvery command area. KAUM 103-104-1, KAUM 95-1, RP 4656-IR73678-6-9-B, RP 4697-52-1-1182 and CR AC 34997 were found promising under retesting. MTU-2077, IET-8110 and MTU-2070 varieties were identified as resistance to BPH in Tungabhadra project area.

Harini *et al.* (2010) in the present study, an attempt was made to validate and fine-map the genetic locus associated with brown planthopper (BPH) resistance locus from IR71033-62-24, a derivative of *O. sativa*/*O. minuta* cross, using simple sequence repeats (SSR markers). AF6 segregating population 300 individuals were developed by crossing IR71033-62-24 with a highly susceptible variety, Mahsuri scoring 4.5 and 9.0 (on the scale 1-9) to BPH in greenhouse screening experiments.

Santhanalakshmi *et al.* (2010) evaluated the 106 F3 families along with their parents Swarna and Ptb33 for resistance to brown planthopper of Indian biotype using the standard seed box technique of IRRI. The donor parent, Ptb33 was found to be highly resistant to the Indian biotype, while the popular variety Swarna was BPH susceptible. The response of F3 progeny was assayed directly based on the phenotypic score. Among the 106 F3 families screened for resistance, the percentage of resistant progeny was between 60-70 per cent of total progeny.

Kumar *et al.* (2012) studies on new sources for resistance against rice brown planthopper (BPH) were undertaken under glass house conditions. Among the 191 National Screening Nursery (NSN) entries evaluated, Swarnadhan was found to be highly resistant, CN 1870 was resistant and HKR 05–22, JGL-16267, UPR 2973-18-2-1, CR 2499-68-10, WGL-309, CR 3080-3-2-5-2, NDR-359 and IR-64 were moderately resistant against brown planthopper.

Tripathi, (2012) five hundred eighty seven rice genotypes were screened against *Nilaparvata lugens*, out of these 20 were categorized as highly resistant, 82 as resistant, 150 as moderately resistant and rest of the other as moderately susceptible and susceptible to BPH. Among all the genotypes screened, the genotype Ganjeikalli had the least plant damage score (0.54) followed by R 1688-2077-1-262-1(0.63) due to BPH infestation.

2.3 Studies on nymphal survival of Brown planthopper, (BPH) *Nilaparvata lugens* (Stal.) on rice genotypes

The survival rates of BPH on different rice varieties were: Xiushui 48, 100%; Xiushui 620, 44% and Jia 23, 28.22%. There exist positive relationship between relative intake amount of BPH (Area of honeydew excreted by BPH) and resistance grade of rice variety, cumulative insect-days per hill, survival rate, oviposition amount of BPH. The rates of population increase of BPH on different resistant varieties were 0.1221 on Xiushui 48; 0.0880 on Xiushui 620 and 0.0830 on Jia 23-2 (Gao *et al*. 1992)

Shuguang *et al*. (2000) study the effects of different rice varieties on the biological properties of brown plant hopper (BPH). The results indicated that rice variety mainly affects the nymphs survival rate and the adult oviposition. No significant difference was observed in nymphs development and adult longevity when BPH was reared on the tested nine different varieties. The biological parameters of BPH population always change with rice varieties, so it is considered that the resistance of rice variety to BPH is very complicated.

Soundararajan *et al*. (2003) conducted pot experiments on 15 day old seedlings of 104 rice double haploid (DH) lines to determine their antibiosis effect on the growth and adult longevity of brown planthopper (BPH) *Nilaparvata lugens*. The growth index of BPH ranged from 2.81 to 7.75. The highest growth index of 7.75 was observed on the susceptible control TN1. The mean growth index of BPH was 4.93. DH 398 showed a maximum growth index of 7.35 followed by DH 116 (7.34).

Reddy *et al*. (2005) studied in a greenhouse the antibiosis mechanism of resistance against BPH in seven resistant (INRC-8815, 7069, 8754, 8712, 7197, 6153 and 7040) and three moderately resistant (INRC-7143, 6165 and 7318) rice genotypes along with a resistant control (Ptb33) and a susceptible control (TN1). The BPH caged with resistant and moderately resistant genotypes had prolonged nymphal development, slow growth and low survival compared to the insects caged with the susceptible control TN1. The nymphal survival on resistant genotypes INRC 8815 was only 32.5 per cent and was on par with resistant check Ptb33. The survival was below 50 per cent in INRC 7069 and INRC 8754 as compared to the 90 per cent survival on susceptible check TN1.

Maheshwari *et al*. (2006) studied mechanisms of resistance i.e. antixenosis and antibiosis against *Nilaparvata lugens* in 5 rice genotypes CORH2 (IR

58025A/C20R), IR 58025A (IR4843A/PUSA 167-120-3-28), C20R, C10, IET 15423, TN1, Ptb33 and IR54742-22-19-3R. Comparatively the nymphal development was prolonged in resistant genotypes by 3.8 to 6.4 days compared to 9.40 days in susceptible TN1.

Alagar and Suresh (2007a) studied antibiosis mechanism of resistance to BPH on selected rice genotypes and found that survival of *Nilaparvata lugens* nymphs was ranged from 50.0 to 82.0 and 32.0 to 80.0 per cent on 30 and 60 day old plants, respectively. They also stated that among the genotypes tested, 30 day old plants of ARC 10550 supported significantly the lowest nymphal survival of 50.0 per cent. It was followed by ADT 45 (52.0%), ASD 7(54.0%), ARC 6650 (58.0%) and Jeeraga samba (60.0%), which were on par with each other compared to 82.0% on TN1. On 60 days old plants, the lowest nymphal survival was recorded on ASD 7 and ADT 45 (32.0%) which was 20.50 fold lower than the susceptible TN1 (80.0%). Among the genotypes tested, 30 day old KAU 1661 recorded the highest nymphal developmental period of 18.53 days, which was 6.86 days higher than TN1 followed by ARC 10550 (18.47 days) and W1263 (17.20 days). While, minimum nymphal developmental period of 9.67 days was observed on CO 46 which was even lower than the susceptible check TN1 (11.67 days). They also observed that ARC 10550 recorded the lowest growth index of *N. lugens* (2.71) on 30 day old plants followed by W 1263(3.14). These were on par with each other compared to 2.74 and 7.03 on Ptb33 and TN1, respectively.

Singh *et al*. (2008) used mutants of rice ‘IR64’ to isolate new sources of resistance to the planthopper *Nilaparvata lugens* (Stal.) (Hemiptera: Delphacidae). In their experiment it was found that nymphal survival and adult female weight did not differ among rice cultivars.

Seo, *et al*. (2009) conducted a nymphal survivorship test and electrical penetration graph (EPG) study on susceptible and resistant rice varieties with four different BPH populations, which were collected in the early 1980s (S-BPH), 2005, 2006, and 2007. The S-BPH showed low survival rates on resistant rice varieties carrying Bph1 and bph2. However, recent wild BPH populations seemed to have high resistance breaking ability according to elevated survival rates on most other resistant rice varieties, except Gayabyeo (Bph1 + bph2) and Rathu Heenati (Bph3).

Vanitha *et al*. (2011) evaluated a set of one hundred and eighty recombinant inbred lines (RILs) from a cross Basmati370/ASD16 were subjected to green house screening to assess the level of BPH resistance. Phenotypic analysis of parents and the RILs were carried out using the screening. *viz*., nymphal settling preference, nymphal survival, nymphal developmental period, growth index, sex differentiation, wing dimorphism, population build-up, functional plant loss index (FPLI) and plant dry weight loss index (PDWLI) and correlation analysis was carried out.

Kumar *et al*. (2012) studies antibiosis mechanism of resistance against BPH w as studied in thirty rice entries with different level of resistance. Per cent nymphal survival, growth index values, population buildup, average nymphal emergence and adult longevity were significantly lower while nymphal duration was found longer as compared to susceptible check (TN1) on different resistant entries studied.

2.4 Studies on 'Ovicidal Test' of brown planthopper (BPH) *Nilaparvata lugens* (Stal.) on rice genotypes

Manjunath, (1977) studied the preovipostion period, oviposition period, longevity and fecundity of the macropterous and brachypterous females of the rice brown planthopper, *Nilaparvata lugens* Stal, averaged 2·9 and 3·0 days; 8·4 and 9·2 days; 10·5 and 16·5 days; and 421·8 and 485·8, respectively. The egg-laying habit of this pest is described and its daily rate of oviposition illustrated.

Nanda *et al*. (1999) conducted laboratory experiments to study the antibiosis mechanism of resistance in 10 rice varieties to the brown planthopper, *Nilaparvata lugens*. They found that the fecundity was maximum on TN1 as compared to other varieties namely Mudgo, ASD 7, Rathu Heenati, Babawee, ARC 6650, Utri Rajpan, Udaya, Pratap and Ptb33.

Hattori and sogawa (2002) oviposition behavior of *Nilaparvata lugens* (Stal.) (Homoptera: Delphacidae) on rice, *Oryzae sativa* L., was monitored using a videocamera and an AC (alternating-current) electronic measuring system. Oviposition by *N. lugens* always took place during stylet penetration into the plant. After penetration of the ovipositor, there were three specific ovipositional sequences observed; sawing insertion of the ovipositor, release of an egg in the plant, and partial or complete withdrawal of the ovipositor from the plant. Distinctive waveforms were recorded in correlating with these events. From a sequence of waveform patterns, it was possible to determine the number of eggs and egg masses laid inside the plant tissue and the duration of oviposition behavior. Waveform analysis revealed that *N. lugens* laid an egg mass consisting of on average 5.7 eggs. This occurred 4.3 min after a period of about 6.4 min of stylet penetration, and this sequence was repeated several times in 24 h. Electrical and/or tethering effects on oviposition appear to be negligible within 24 h of recording.

Reddy *et al*. (2005) studied the antibiosis mechanism of resistance against BPH in seven resistant (INRC-8815, 7069, 8754, 8712, 7197, 6153 and 7040) and three moderately resistant (INRC-7143, 6165 and 7318) rice genotypes along with a resistant control Ptb33 and a susceptible control TN1 in greenhouse. Low fecundity of BPH was found on resistant and moderately resistant genotypes as well as on resistant check Ptb33 as compared to the susceptible check TN1. The hatchability of eggs was low in INRC 8815 and resistant check Ptb33. The egg hatchability was below 73 per cent in resistant genotypes and below 77 per cent in moderately resistant genotypes and was 95 per cent in susceptible check TN1.

Maheshwari *et al*. (2006) studied mechanisms of resistance i.e. antixenosis and antibiosis against *Nilaparvata lugens* in 5 rice genotypes CORH2 (IR 58025A/C20R), IR 58025A (IR4843A/PUSA 167-120-3-28), C20R, C10, IET 15423, TN1, Ptb33 and IR54742-22-19-3R. Comparatively less fecundity and hatchability was recorded in all resistant genotypes than the susceptible TN1. The mean number of nymphs emerged was significantly high in susceptible TN1 (96.8), while very low nymphal population ranging from 38.0 to 41.1 were observed among resistant genotypes. The number of unhatched eggs varied from 50.6 to 54.2 among the resistant genotypes.

Alagar and Suresh (2007b) studied oviposition behaviour of BPH. Among the genotypes tested, ASD 16 recorded significantly lowest number of nymphal emergence (122.0 number/plant) which was 61.1 per cent lower than TN1 followed by Pusa Basmati (137.2), Jeeraga samba (143.2), ARC 10550 (146.6) and IR (150.6), which were on par with each other. Basmati 370 recorded significantly the highest percentage of unhatched eggs (25.4%) followed by ASD 16 (25.1 %) compared to TN1 which recorded the lowest value of 2.5 per cent.

Wada *et al*. (2007) investigated the pre ovipositional period of *Nilaparvata lugens* originating from tropical, subtropical and temperate regions of East and Southeast Asia using laboratory experiments to compare the migration capability of the populations. Macropterous females collected in 1992 from Japan and subtropical North Vietnam had a longer immature period than those from tropical Indochina Peninsula, *i.e.* the day of the first oviposition after eclosion was about 3 days later in the former populations.

Khinkhin *et al*. (2009) observed oviposition of BPH on near isogenic lines (NILs) and pyramided line PYL of rice. In the Hatano 66 strain, few eggs were laid on the two NILs, their PYL and ADR52 ranging from 24.6 to 31.8 compared with 95.8 on T65. In the case of Isahaya 99 and Nishigoshi 05 strains, the large numbers of eggs laid on the two NILs was similar to that on the susceptible check T65, but few eggs were laid on the PYL and ADR52 compared to T65.

Satpathi *et al*. (2011) the seasonal variation on life table of the brown planthopper *Nilaparvata lugens* Stal. (BPH) in Eastern India indicated that the net fecundity rate is higher in rainy season (79.24) than winter (36.43). Identical trends of the net reproductive rate (Rt) and intrinsic rate of increase (rm), finite rate of increase were observed as 31.51 and 0.1286023, 1.1372370 in rainy/kharif season and 9.38, 0.0702774, 1.0728057 in winter respectively. Although the weekly multiplication (rw) of BPH is higher in rainy/ kharif (2.4601354) than winter/ rabi (1.66469120) but the mean length of generation (T) and doubling time of population (DT) were lower in rainy/ kharif (34.00,5.38) than winter/ rabi as recorded 51.16, 9.86 in the plains of west Bengal during 2010-2011. Likewise the instars wise life table study also showed that the maximum 234 eggs were laid by single female of which ultimately 96 adults were produced after 23 days during the month of October and November 2010. Different mortality factors causes 23.50%, 17.87%, 21.76%, and 7.82%, and 7.76% and 2.0 % death on egg, first, second, third, fourth, fifth instar stages of this insect respectively.

Xiaolin *et al*. (2011) the brown planthopper (BPH), *Nilaparvata lugens*, is the most devastating rice pest in many areas throughout Asia. The reproductive system of female *N. lugens* consists of a pair of ovaries with 24-33 ovarioles per ovary in most individuals which determine its fecundity. The fork head (Fox) is a transcriptional regulatory molecule, which regulates and controls many physiological processes in eukaryotes. The Fox family has several subclasses and members, and several Fox factors have been reported to be involved in regulating fecundity.

2.5 Probing mark test of brown planthopper *Nilaparvata lugens* (Stal.) on evaluvated rice genotype

The result of probing behavior indicating that the resistant varieties received more number of probing punctures than the susceptible one (Reddy, 1979; Reddy and Kalode, 1985 and Veronica, 1985).

The electronic measurement system greatly facilitates the behavioral study of feeding and probing by piercing and sucking insects on susceptible and resistant plants (Kawabe *et al*., 1981; Velusamy and Heinrichs, 1986).

In laboratory studies with six varieties of rice adult brachypterous female of *Nilaparvata lugens* (Stal.) made more probing marks, produced less honeydew and gained less body weight on resistant than on susceptible varieties (Bagui, 1989).

The probing behaviour of different biotypes of *Nilaparvata lugens* (Stal.) on TN1 (Susceptible variety) and IR-26 and ASD7 (two resistant varieties of rice) were compared. There were no obvious differences among the probing frequencies of biotype 2 on these three varieties. Under no-choice feeding conditions, the probing frequencies of biotype 1 on TN1 increased significantly and that of biotype 3 on ASD 7 increased significantly (Lu *et al*., 1999).

In all the seven selected resistant rice genotypes, the average probing marks per seedling ranged from 19 to 32, although, in resistant check (ptb33) variety, the probe marks was 29 per seedling, which was significantly at par with six resistant rice genotypes (Urre *et al.,* 2004b).

Sable (2010) investigated the probing behaviour of BPH on sixteen resistant rice genotypes. The probing frequency ranged from 21.40 to 38.80 which was significantly higher than susceptible check TN1 (10.33).

Rana and Dubey (2010) studied the probing marks behaviour of BPH on 23 selected resistant rice donors. The probing marks ranged from 13.10 to 25.10 which was significantly higher than susceptible check TN1 (10.33).

Ponnada *et al.* (2011) studied on six selected highly resistant advanced rice breeding lines along with a resistant check (Ptb-33) and susceptible check (TN-1). After standard screening evaluation the damage score ranged between 0.1 to 0.5, 2.4 and 9.0, respectively. All selected highly resistant lines exhibited significantly lowest feeding and highest probing marks. Feeding values ranged between 4. 0 to 11.45 mm^2 per female and probe number between 30. 4 to 42.9 per female on test seedlings.

Materials and Methods

CHAPTER- III

MATERIALS AND METHODS

The present investigation entitled **"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes"** were carried out in the Glass House, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during 2012 - 2013.

The experimental material consisted of 167 (One hundred sixty seven) rice genotypes received from the Department of Genetics and Plant Breeding along with TN1 and Ptb33 as standard susceptible and resistant checks, respectively. Out of these 167 rice genotypes, the materials used and techniques employed for conducting various experiments are presented under following heads.

3.1 **Mass rearing**

To get the regular supply of insect for various studies, the brown planthopper (BPH), was mass reared initially at 30° ± 5°C on potted TN1 (Taichung Native) variety and the population was maintained throughout the year in the air cooled glass house. Brown planthopper population were reared on 40 to 45 days old TN1 plants, inside the rearing cage of 75x75x75 cm size consisting of wooden frame with small window on front side and fine wire mesh on top sides. Cages were mounted on cemented platform with a water level of 7.5 cm height to avoid the entry of ants and other crawling insects and also to maintain moisture in glass house. Mass rearing of brown planthopper is shown in Plate 2.

Potted TN1 plants were placed inside the rearing cages for egg laying along with at least 3-4 pairs (Male and Female) of brown planthopper per hill. After 2-3 days, the females started egg laying inside the leaf sheath of paddy plants. Later on, after emergence of nymphs from plants, released brown planthopper pairs were transferred to another TN1 plant with the help of aspirator for egg laying. When newly emerged nymphs reached to second instar, they were used for screening of rice genotypes. Likewise, the multiplication process of brown planthopper insect continued for screening of rice genotypes, nymphal survival, and oviposition test, probing mark test.

3.2 Screening of rice genotypes for resistant to brown planthopper *Nilaparvata lugens* (Stal.) in glass house condition

Screening of rice genotypes was carried out as per methodology suggested by Kalode *et al*. (1979). The test and check genotypes were pre-germinated in petridishes (10 cm diameter) and these germinated seeds were sown in rows 5 cm apart in 50 x 40 x 7 cm wooden/plastic trays, containing well puddled homogenous soil. Each tray accommodated 10-12 rows of test entries with 20 seedlings in each row. In middle separate rows of check Ptb33, TN1 and at border two rows of TN1 were sown. Layout of screening of rice genotypes is shown in Fig 3.1.

The wooden/plastic trays were placed in 7.5 cm deep water on cement platform to maintain humidity suited to the insect development and to keep away ants. When the seedling attain about 7 to 10 days old age, sufficient number of first and second instar nymphs were uniformly released on these seedlings, so that each seedling must be get infested with at least 8 to 10 nymphs approximately. Screening of rice genotypes in glass house condition is shown in Plate 3.

The observations were recorded on the basis of 0-9 scale, when more than 90 percent TN1 seedling were killed by the brown planthopper insect. The whole reaction was completed in 7-10 days after the release of insects. Comparative infestation of BPH on different rice genotypes is shown in Plate 4.

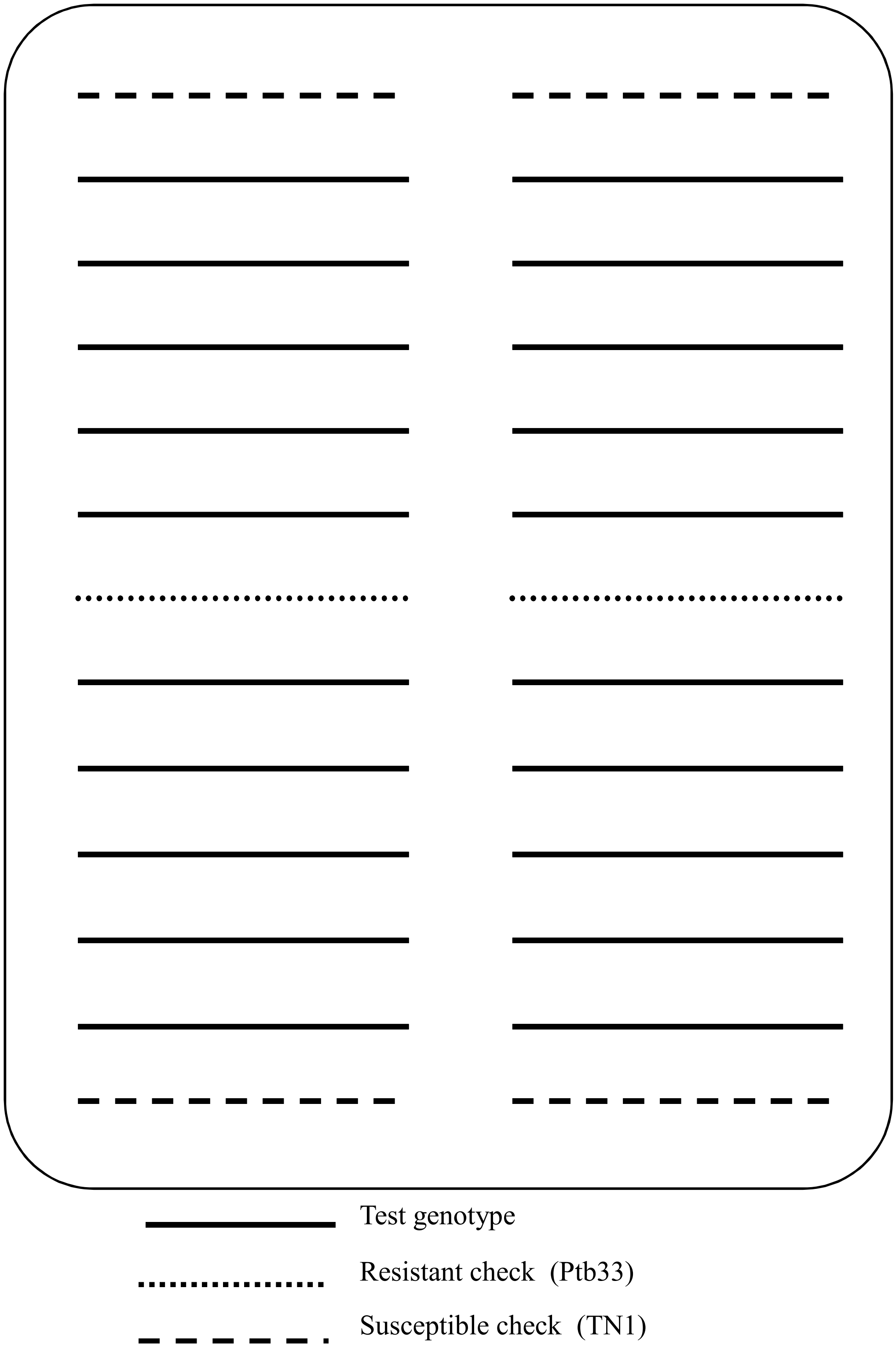


Fig.3.1: Layout of screening of rice genotypes for resistant to BPH

Observations of seedlings were taken on the basis of visual plant damage symptoms (0-9 scale) which are as follows:

Score*	Rating	Symptoms
0	Highly resistant	No visible damage
1	Resistant	Partial yellowing at first leaf
3	Moderately resistant	Partial yellowing first and second leaves
5	Moderately susceptible	Pronounced yellowing and some wilting
7	Susceptible	More than halves of the plants are wilted or dead and remaining plants severely stunted
9	Highly susceptible	All plants dead

*Mean score of plant damage was calculated. (Anonymous, 1996)

3.3 Nymphal Survival response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes

The well germinated seeds of selected rice genotypes were sown in 500 ml plastic/earthen pots filled with fertilizer enriched puddled soil. After 30 days, the plants were covered by the Mylar tube with ventilating windows. Then 10 nymphs (First and second instar) were released in such tubes then the open end of the tube covered by the muslin cloth and tied with rubber band. For each variety six replications were kept. The plants were observed daily for the emergence of the adult. These emerged adults were removed from the tubes and observation on sex form of the adults was noted down. The nymphal survival test is shown in Plate 5.

The percent nymphal survival calculated by using following formula (Heinrichs *et al*., 1985).

Plate- 2: Mass rearing- Showing first and second instar nymphs of BPH

Plate-3: Screening material of rice genotypes against BPH

$$\text{Per cent nymphal survival} = \frac{\text{Number of adult emerged}}{\text{Number of nymphs released}} \times 100$$

Developmental period was studied by counting the days taken by the nymphs to reach the adult stage (Pongprasert and Weerapat, 1979). Growth index (GI) of BPH on each genotype was computed from the data obtained from the experiments on nymphal survival and developmental period as below (Pablo, 1977; Panda and Heinrichs, 1983).

$$\text{Growth Index (GI)} = \frac{\text{Per cent of nymphs survived}}{\text{Mean developmental period}}$$

Lower nymphal survival and slow growth rate reflects the antibiosis (Alarn and Cohen, 1998).

3.4 Ovipositional response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes

Ovipositional test was carried out as per method adopted by Reddy *et al.* (2005). The well germinated seeds of selected rice genotypes were sown in 500 ml plastic/earthen pots filled with fertilizer enriched puddled soil. Six replications were maintained for each variety. After 30 days the plant was covered with Mylar tube with ventilating windows. One pair of adult *i.e.* one gravid female and male was introduced with the help of aspirator in the Mylar tube then the open end was closed with a muslin cloth and tied with a rubber band. After five days (120 hrs), the adults were removed from the cage. Ovicidal test for different rice genotypes is shown in Plate 6.

The plants were observed for the nymphal emergence. The emerged nymphs were counted and removed from the plant. After all the eggs are hatched or when nymphs stop coming out *i.e.* after 15-20 days of adult release, the plants are cut at base and examined under microscope to count and record total number of unhatched

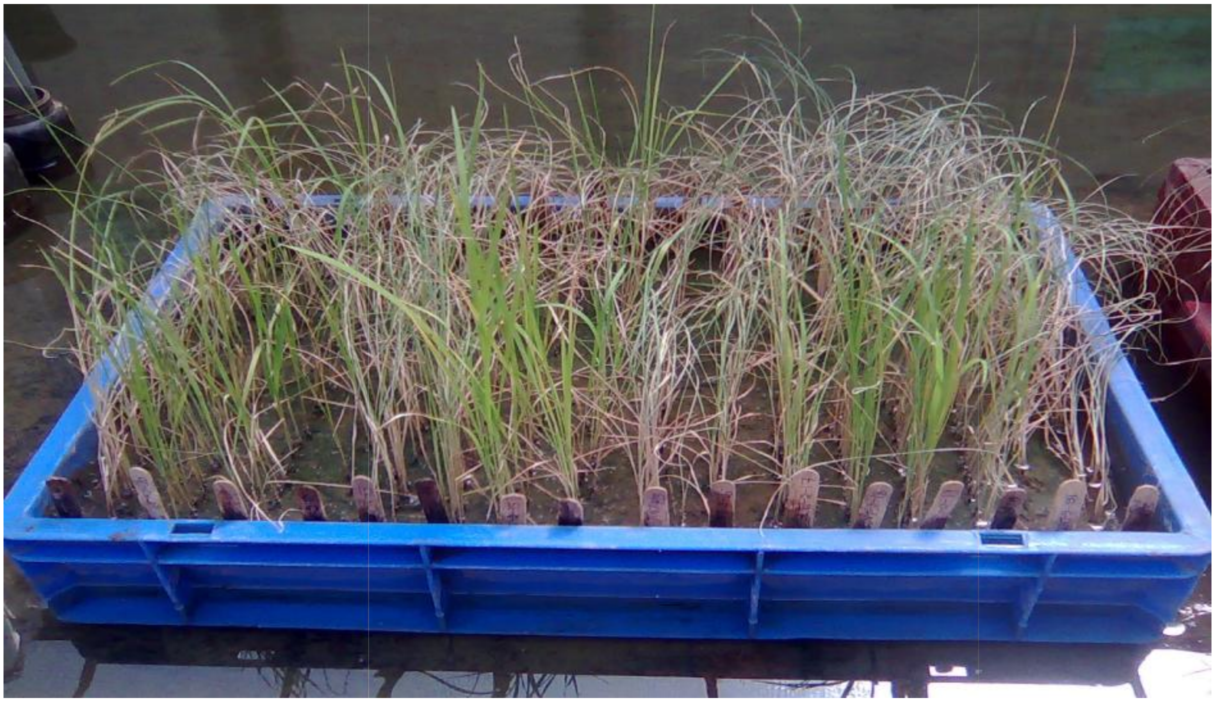


Plate-4: Comparative infestation of BPH on rice genotypes

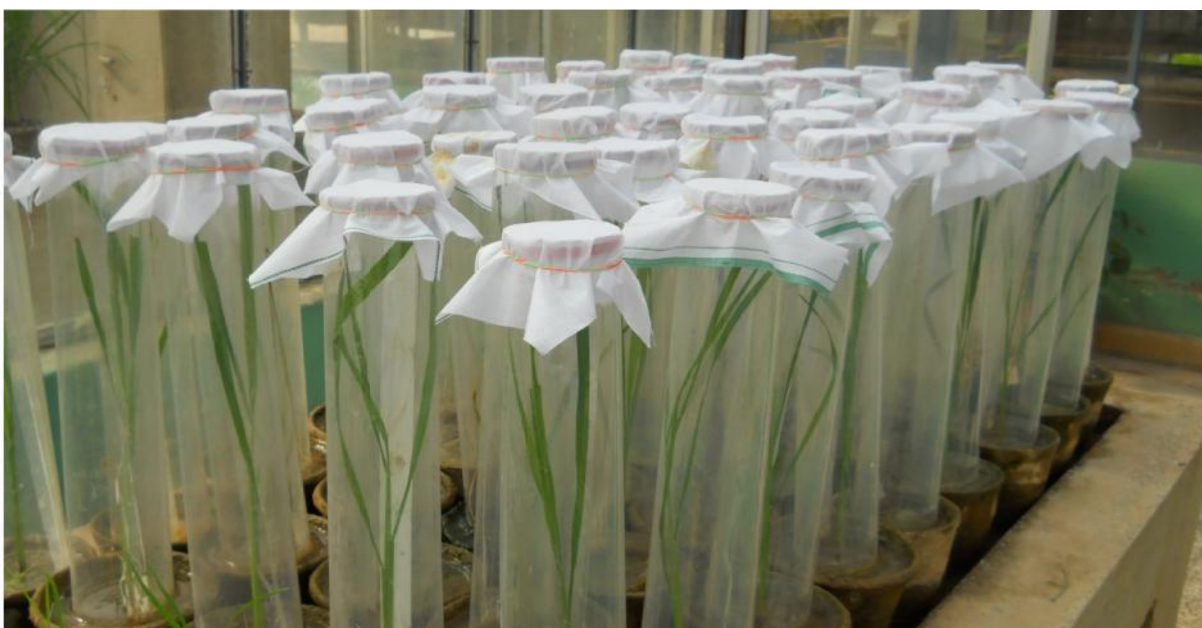


Plate-5: Nymphal survival test on resistant rice genotypes

eggs. Unhatched eggs was expressed as percentage of total, which is sum of the number of nymphs emerged and number of unhatched eggs.

$$\text{Per cent of unhatched eggs} = \frac{\text{Number of unhatched eggs}}{\text{Number of nymphs emerged} + \text{Number of unhatched eggs}} \times 100$$

3.5 Probing mark test of brown planthopper *Nilaparvata lugens* (Stal.) on evaluated rice genotype

Probing mark test was carried out according to methodology suggested by Natio (1964). For this purpose, seeds of identified resistant rice genotypes and check varieties i.e. TN1 and Ptb33 were germinated separately in petridishes. Germinated seeds were sown in wooden/plastic trays containing well puddled soil. After seven days, the seedling of each variety was removed from trays and washed thoroughly with water and then transferred individually into 15 cm long test tubes containing a few drops of water. One female (two days old) was introduced individually into each test tube and test tubes were plugged with sterilized cotton swab. The female was allowed to make punctures on the seedling for overnight (12 hrs). Thereafter, the seedlings were taken for staining in another tube containing 1.0 per cent erythrosine dye aqueous solution. The probing mark test is shown in Plate 7. Insect probing marks stained thereby counted visually after 30 minutes of staining. Ten replicates were maintained for each rice genotypes and each replicate contains one seedling.

3.6 Statistical analysis

All the observations on probing mark test, nymphal survival, and oviposition test were recorded and tabulated in a systematic manner. The final observations were statistically analyzed in complete randomized block design (CRD) with necessary transformation.

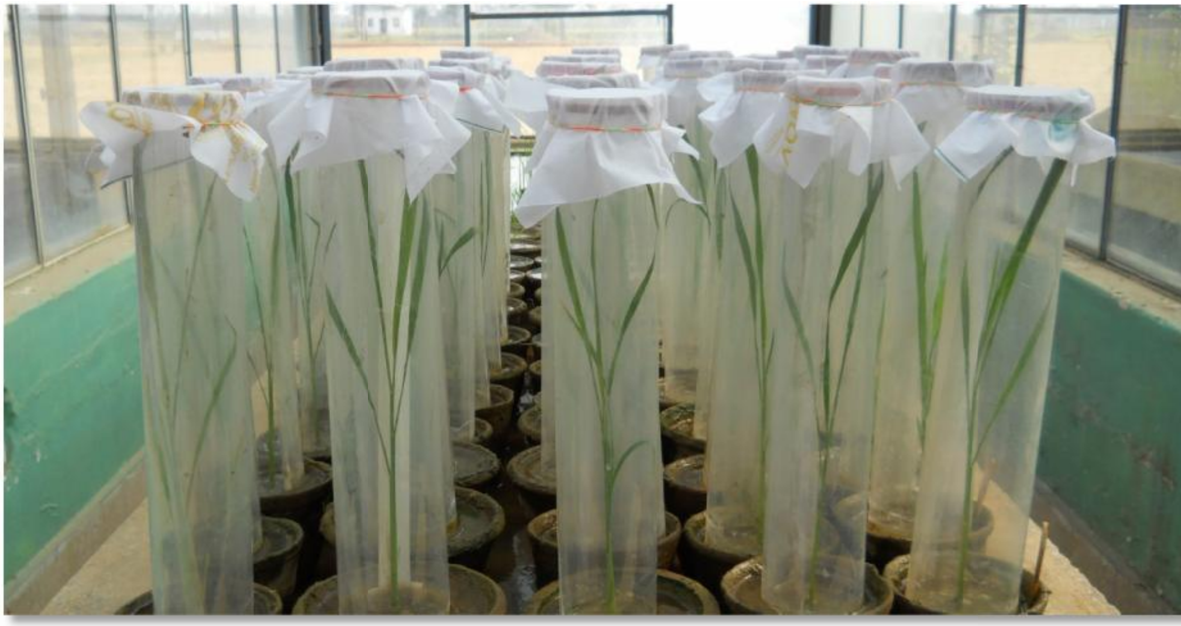


Plate-6: Ovicidal test for BPH on different rice genotypes

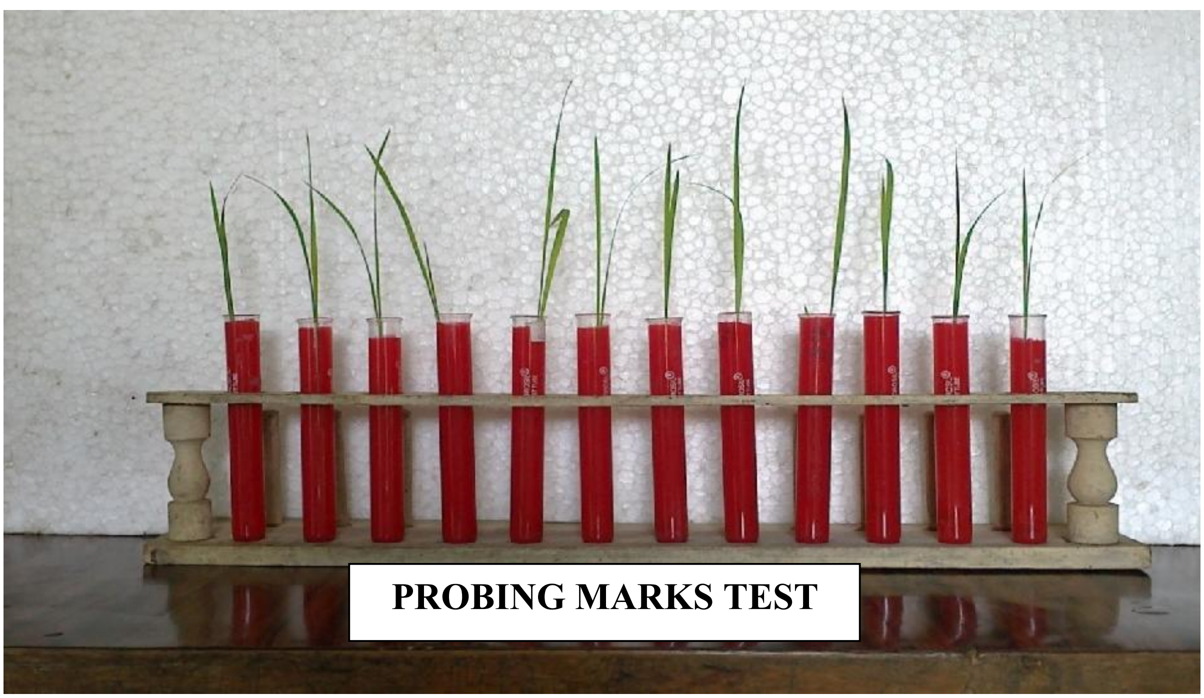


Plate-7: Probing mark test- Staining with 1.0% erythrosine solution

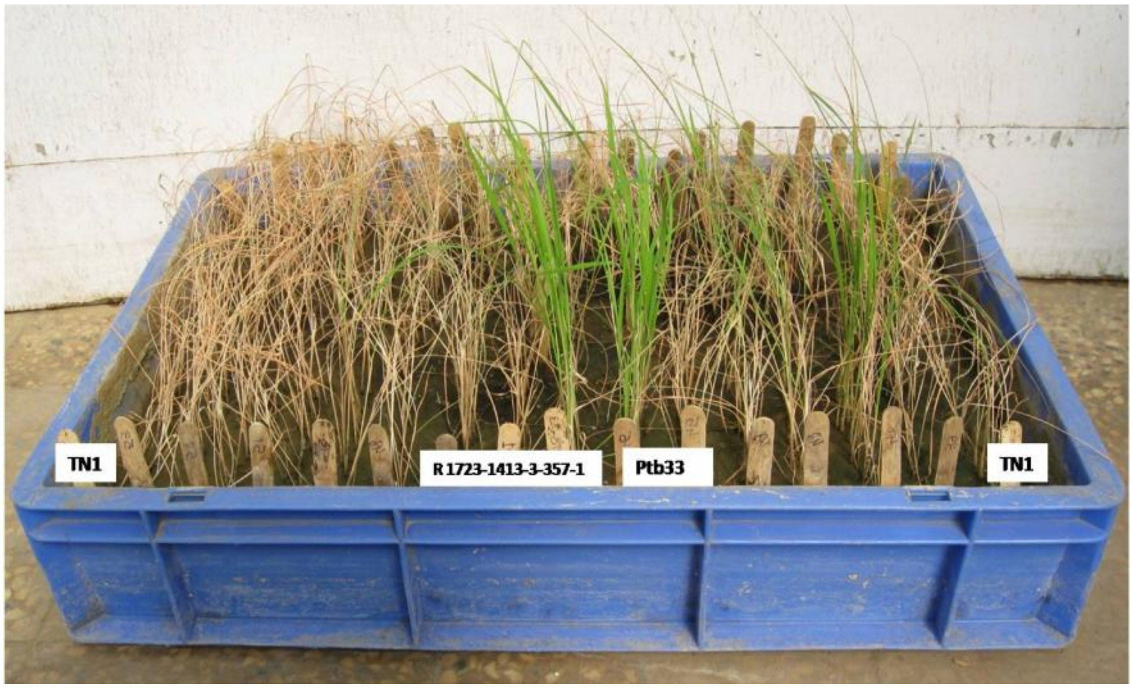


Plate-8: Rice genotype R1723-1413-3-357-1 and Ptb33 showing resistant to BPH

Result and Discussion

CHAPTER- IV

RESULT AND DISCUSSION

This chapter deals with the brief description of results obtained under different objectives of the experiment entitled **"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes"** The findings of the present study are compared with the previous findings of the relevant aspects in justified manner to draw a concrete conclusion. The results and discussion are presented here under different sub headings:

1. Screening of rice genotype for resistant to brown planthopper *Nilaparvata lugens* (Stal.) in glass house condition.

2. Nymphal survival response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.

3. Ovipositional response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.

4. Probing mark test of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes.

Table 4.1: Plant damage score of resistant rice genotypes caused by BPH, *Nilaparvata lugens* (Stal.)

Sr.N0.	Designation	Parentages	*Average plant damage score
1	R 1723-1413-3-357-1	Nidhee x IR 36	1.03
2	R 1688-2077-1-262-1	R 975-897-1-1 x Tarori Basmati	1.04
3	IR 78554-145-1-3-2	Not Available	1.13
4	R 1688-2077-1-262-1	R 975-897-1-1 x Tarori Basmati	1.24
5	Dubraj (Rajeev)	Not Available	1.26
6	R 1458-231-1-275-1	Abhaya / Madhri	1.33
7	R 1700-301-1-155-1	Danteshwari x Amrit Bhog	1.35
8	R 1605-315-1-31-1	SR 12 x Jira Shanker	1.46
9	R 1667-1025-1-97-1	R 1060-1674-1-1 x Chandrahasini	1.47
10	R 1747-4941-1-515-1	Rastic Br 240-47 x Shay- Jira	1.49
11	R 1700-304-1-161-1	Danteshwari x Amrit Bhog	1.54
12	R 1675-1844-2-1257-1	R 1037-649-1-1 x Mahamaya	1.58
13	R 1656-1146-5-513-1	Swarna x Jira Shanker	1.59
14	Indira Sugandhit Dhan 1	(Check)	1.61
15	IR 81166-29-1-2-3	Not Available	1.61
16	R 1700-2243-2-2312-1	Danteshwari x Amrit Bhog	1.74
17	R 1723-1411-1-355-1	Nidhee x IR 36	1.75
18	R 1757-540-3-286-1	IR 64 x Bishanu Bhog	1.81
19	PSB RC 68	Not available	1.84
20	R 1682-1997-6-1754-1	IR 36 x Triguna	1.92
21	R 1688-2150-5-2660-1	R 975-897-1-1 x Tarori Basmati	1.92
22	R 1700-309-1-171-1	Danteshwari x Amrit Bhog	1.95
23	R 1744-4901-1-510-1	IR 36 x Pau 3056	2.02
24	R 1695-2169-1-274-1	Danteshwari x Poornima	2.05
25	R 1700-2240-4-2295-1	Danteshwari x Amrit Bhog	2.06

26	R 1700-2240-4-2295-1	Danteshwari x Amrit Bhog	2.10
27	R 1700-302-1-156-1	Danteshwari x Amrit Bhog	2.15
28	R 1720-2550-4-2644-1	BG 380-2 x IR 64	2.15
29	R 1536-1170-5-140-1	R 302-111 x Ganga Baru	2.21
30	R 1700-308-3-170-1	Danteshwari x Amrit Bhog	2.23
31	IR 64	(Check)	2.25
32	IR 83376 B – B 110-3	Not available	2.28
33	R 1629-234-7-1884-1	HMT x Jira Shanker	2.29
34	PR 26703-3-B – PT25	Not available	2.33
35	IR 77537-24-1-1-3	Not Available	2.36
36	R 1711-2485-4-2593-1	R 1037-649-1-1 x Nidhee	2.37
37	Chandrahasini	(Check)	2.48
38	R 1656-1199-2-551-1	Swarna x Jira Shanker	2.53
39	R 1652-2701-2915-1	Madhuri x R 979-1528-2-1-1	2.82

* Plant damage score based on 0-9 scale.
* Average plant damage score based on 3 replications.

4.1 Screening of rice genotype for resistant to brown planthopper *Nilaparvata lugens* (Stal.) in glass house condition

A total of 167 rice genotypes procured from department of Genetics and Plant Breeding, IGKV, Raipur were evaluated against BPH in glass house by adopting internationally accepted standard seed box screening technique.

Among 167 rice genotypes tested, 39 were categorized as resistant, 24 as moderately resistant, 12 as moderately susceptible and rest of other 92 genotypes were susceptible to BPH.

The average plant damage score of resistant genotypes ranged from 1.03 to 2.82 (Table 4.1). The genotype R 1723-1413-3-357-1 showed the least plant damage score (1.03) followed by R 1668-2077-1-262-1 (1.04) and IR 78554-145-1-3-2 (1.13), whereas it was highest in R 1652-2701-2915-1 (2.82) followed by R 1656-1199-2-551-1 (2.53) and Chandrahasini (2.48). The resistant reaction of rice genotype R 1723-1413-3-357-1 and Ptb33 is shown in plate 8.

The average plant damage score of moderately resistant genotypes ranged from 3.00 to 4.98 (Table 4.2). Among moderately resistant genotypes tested, the genotype showed least R 1553-1369-2-252-1 (3.00) plant damage score followed by R1860-783-3-426-1 and Indira Sugandhit Dhan 1 (3.1) while it was the highest in the genotype R 1599-594-2-305-1 (4.98) followed by R 1670-1134-1-115-1 (4.89) and R1860-783-2-425-1 (4.87).

The average plant damage score of moderately susceptible and susceptible rice genotypes are shown in Table 4.3 and Table 4.4, respectively.

The average plant damage score in resistant check Ptb 33 was observed 1.06. Similarly, varied level of resistant reaction in rice genotypes against BPH have been reported by several workers *viz*. Velusamy (1991), evaluated one hundred ninety five

Table 4.2: Plant damage score of moderately resistant rice genotypes caused by BPH, *Nilaparvata lugens* (Stal.)

Sr.No.	Designation	Parentages	*Average plant damage score
1	R 1553-1369-2-252-1	Mahamya / Nidhee	3.00
2	R 1625-1211-2-765-1	Denteshwari / Tarori Basmati	3.10
3	R1860-783-3-426-1	R 1099-2596-1-1x RF13	3.10
4	R 1519-781-1-594-1	Rastic Br 240-47 / Charder	3.15
5	IRH 43	Not Available	3.17
6	R 1518-725-849-3	IR 64 / Laxmi Bhog	3.21
7	R 1695-2152-1-268-1	Danteshwari x Poornima	3.27
8	R 1661-1372-1-601-1	R 1004-5552-1-1 x Nagri Dubraj	3.30
9	Jaya	(Check)	3.32
10	Sasyasree	(Check)	3.41
11	R1902-917-1-517-1	Denteshwari x JGL 1118	3.50
12	R 1432-251-103-1-1	IET 14876 / Pusa Basmati-1	3.67
13	R 1938-620-1-163-1	Abhaya x B 644-FMR-6-0-0	3.73
14	R1656-77-1-45-1	Swarna x Jira Shankar	3.76
15	R 1677-1891-3-1435-1	R 1037-649-1-1 x Danteshwari	3.80
16	R 1678-4410-1-493-1	R 1037-649-1-1 x Poornima	4.00
17	R 1677-1891-3-1435-1	R 1037-649-1-1 x Danteshwari	4.24
18	R 1677-1880-8-1381-1	R 1037-649-1-1 x Danteshwari	4.26
19	IRH-84	Not Available	4.29
20	R 1695-2169-1-274-1	Danteshwari x Poornima	4.66
21	R 1779-311-2-103-1	Danteshwari x WGL 320100	4.73
22	R1860-783-2-425-1	R 1099-2596-1-1x RF13	4.87
23	R 1670-1134-1-115-1	Samleshwari x Poornima	4.89
24	R 1599-594-2-305-1	MTU 1010 x Mahamaya	4.98

* Plant damage score based on 0-9 scale.

* Average plant damage score based on 3 replications.

breeding lines received from *Oryza officinalis* against BPH, 54 lines were exhibited high level of resistant to BPH with score 1. Also, Anonymous (1999) evaluated a total of 1147 cultures and hybrids from different screening nurseries and some breeding material from Mahyco Research Foundation were evaluated against BPH at DRR. A total of 26 culture and hybrids were found promising recording below 3.0 plant damage score on 0-9 scale. Similarly, Pophaly *et al. (*2001) evaluated about 7,500 rice accessions against BPH (*Nilaparvata lugens* Stal) in the glass house at Raipur (C.G.); during, 1992-1998. So far 327 rice accessions were identified with resistance to BPH on a 0-9 internationally accepted plant damage score scale. Anonymous (2002) evaluated a total of 814 entries from screening nurseries/trials against BPH, at DRR, Hyderabad and 32 entries were found promising with a low plant damage score *i.e.* <3.

The variability in reaction pattern in a host plant against any specific pest may be concerned with biophysical and biochemical parameters of the host. Several biophysical parameters *viz*. cellulose, hairs, thick epidermis which might be responsible for imparting the resistant against BPH. Woodhead and padgham (1988) observed presence of thick layers of long cellulose hair on the host preventing the hoppers to establish on host surface, similarly, the varieties having the thick epidermis which provides less passage for the insertion of stylet by the brown planthopper into stem of resistant variety.

There might be some nutrients in host plants, which were correlated with the incidence of BPH. Sujatha *et al*. (1987) stated that phenol, silica, phosphorus, potassium, sulphur and iron content positively correlated with resistance against BPH while the protein, nitrogen, zinc and manganese contents were negatively correlated with BPH resistance in rice. Likewise, Reddy *et al*. (2004) stated that highest per cent

Table 4.3: Plant damage score of moderately susceptible rice genotypes caused by BPH, *Nilaparvata lugens* (Stal.)

Sr.N0.	Designation	Parentages	*Average plant damage score
1	R1750-937-1-530-1	BG380-2xAmrit Bhog	5.06
2	R1702-542-1-287-1	Poornima x R 979-1528-2-1	5.10
3	R 1695-2155-1-270-1	Danteshwari x Poornima	5.11
4	R 1607-673-2-322-1	SR 12 x Chinni Kapoor	5.18
5	CR 2616-3-3-3-1	Not Available	5.19
6	R1629-227-1-1868-2	HMTx Jira Shankar	5.27
7	R1629-234-6-1883-1	HMTx Jira Shankar	5.87
8	IRH-83	Not Available	5.90
9	R 1607-321-1-34-1	SR 12 x Chinni Kapoor	6.21
10	R 1577-642-1-208-1	Triguna / Madhuri-11	6.27
11	R 1536-136-1-77-1 (21842)	R 1536-136-1-77-1	6.47
12	R 1707-2291-3-2392-1	MTU 1001 x Poornima	6.92

* Plant damage score based on 0-9 scale

* Average plant damage score based on 3 replications.

Table 4.4: Plant damage score of susceptible rice genotypes caused by BPH, *Nilaparvata lugens* (Stal.)

Sr.N0.	Designation	Parentages	*Average plant damage score
1	IRH-82	Not Available	7.07
2	R 1600-1124-3-619-1	MTU 1010 x Triguna	7.11
3	Dubraj	(Check)	7.20
4	R1656-420-9-1945-1	Swarna x Jira Shankar	7.20
5	R 1677-1375-1-157-1	R 1037-649-1-1 x Dantehswari	7.22
6	R1629-227-1-1868-2	HMTx Jira Shankar	7.26
7	R 1217-2	SHYAMALA / IR36 / SHYAMALA	7.29
8	R 1677-1375-1-157-1	R 1037-649-1-1 x Dantehswari	7.35
9	R 1695-2193-6-2171-1	Danteshwari x Poornima	7.40
10	R1629-234-8-1885-1	HMTx Jira Shankar	7.45
11	R 1695-2152-2-269-1	Danteshwari x Poornima	7.80
12	Annada	(Check)	9.00
13	Badsha bhog	(Check)	9.00
14	Bamleshwari	(Check)	9.00
15	Chandrahasini	(Check)	9.00
16	Chinnor	(Check)	9.00
17	Danteshwari	(Check)	9.00
18	Ganjeikalli	Not Available	9.00
19	IET 21053 (NDR9542)	Not Available	9.00
20	Indira Sona (hybrid)	(Check)	9.00
21	IR 84887-B-15	MLT 11-24	9.00
22	Karma Mahsuri	(Check)	9.00
23	Mahamaya	(Check)	9.00
24	Mahisugandha	(Check)	9.00

25	Pusa Basmati- 1	(Check)	9.00
26	R 1138-688-3-533-1	IR 64 / Pusa basmati-1	9.00
27	R 1238-696-821-3-1	Mahamaya / R 671	9.00
28	R 1519-815-1-646-1	Rastic Br 240-47 / Charder	9.00
29	R 1521-950-6-843-1 (21841)	R 1521-950-6-843-1	9.00
30	R 1528-106-1-56-1	MTU 1001 / Chatnya	9.00
31	R 1532-1101-1-119-1	Swarna / IET 14074	9.00
32	R 1551-1066-1-449-1	Madhuri x Mahamaya	9.00
33	R 1557-1321-1-591-1	Swarna x Indira - A 13	9.00
34	R 1557-563-1-83-1	Swarna x Indira A 9	9.00
35	R 1625-1203-1-753-1	Denteshwari / Tarori Basmati	9.00
36	R 1625-1204-1-754-1	Denteshwari / Tarori Basmati	9.00
37	R 1630-1237-2-827-1	SR 12 / Laxmi Bhog	9.00
38	R 1641-391-1-61-1	MTU 1001 x Swarna	9.00
39	R 1654-2715-2-2936-1	R 1037-1172-1 x Poornima	9.00
40	R 1656-1146-1-510-1	Swarna x Jira Shankar	9.00
41	R 1656-1146-1-510-1	Swarna x Jira Shankar	9.00
42	R 1656-1146-4-512-1	Swarna x Jira Shankar	9.00
43	R 1656-2816-9-3223-1	Swarna x Jira Shankar	9.00
44	R 1656-2821-1-3245-1	Swarna x Jira Shankar	9.00
45	R 1656-2823-2-3249-1	Swarna x Jira Shankar	9.00
46	R 1656-2826-1-3261-1	Swarna x Jira Shankar	9.00
47	R 1656-3173-1-415-1	Swarna x Jira Shankar	9.00
48	R 1656-3179-2-419-1	Swarna x Jira Shankar	9.00
49	R 1657-2899-1-3333-1	Swarna x Indira - A 9	9.00
50	R 1661-1372-1-601-1	R 1004-5552-1-1 x Nagri Dubraj	9.00
51	R 1661-605-84-1	R 1004-5552-1-1 x Nagri Dubraj	9.00
52	R 1662-1419-2-742-1	R 1004-5552-1-1 x Danteshwari	9.00
53	R 1663-1473-2-816-1	R 1004-5552-1-1 x Poornima	9.00

54	R 1667-1025-1-97-1	R 1060-1674-1-1 x Chandrahasini	9.00
55	R 1670-3975-1-485-1	Samleshwari x Poornima	9.00
56	R 1670-3977-1-486-1	Samleshwari x Poornima	9.00
57	R 1672-4125-488-1	Samleshwari x Dantehswari	9.00
58	R 1678-4411-1-494-1	R 1037-649-1-1 x Poornima	9.00
59	R 1695-2155-1-270-1	Danteshwari x Poornima	9.00
60	R 1698-3644-3-4696-1	Danteshwari x Elaychi	9.00
61	R 1700-2240-1-2292-1	Danteshwari x Amrit Bhog	9.00
62	R 1700-2247-1-2313-1	Danteshwari x Amrit Bhog	9.00
63	R 1702-3677-1-4734-1	Poornima x R 979-1528-2-1	9.00
64	R 1779-320-1-111-1	Danteshwari x WGL 320100	9.00
65	R 1799-311-102-1	Danteshwari x WGL 320100	9.00
66	R 1819-473-1-139-1	Shyamla x MR 219	9.00
67	R 1892-489-1-152-1	R 650-1817 x Pusabasmati	9.00
68	R 1919-573-1-160-1	Shyamla x G 93-02	9.00
69	R1629-222-9-1866-1	HMTx Jira Shankar	9.00
70	R1629-234-1-1878-1	HMTx Jira Shankar	9.00
71	R1656-420-7-1943-1	Swarna x Jira Shankar	9.00
72	R1656-425-4-1949-1	Swarna x Jira Shankar	9.00
73	R1656-428-10-1955-1	Swarna x Jira Shankar	9.00
74	R1656-428-10-1955-1	Swarna x Jira Shankar	9.00
75	R1656-431-10-1975-1	Swarna x Jira Shankar	9.00
76	R1656-431-3-1968-1	Swarna x Jira Shankar	9.00
77	R1672-126-1-64-1	R1027-2282-2-1 x Denteshwari	9.00
78	R1695-270-2-133-1	Denteshwari x Poornima	9.00
79	R1738-504-3-255-1	IR 64x Pusa Basmati	9.00
80	R1738-504-3-255-1	IR 64x Pusa Basmati	9.00
81	R1750-937-1-530-1	BG380-2xAmrit Bhog	9.00
82	R1775-565-1-308-1	Denteshwari x CRN 2202-118	9.00

83	R1902-912-2-512-1	Denteshwari x JGL 1118	9.00
84	R1926-1013-2-595-1	R1130-80-1-52-1xHURFG 4-6	9.00
85	RS 2011-101	Not Available	9.00
86	RS 2011-201	Not Available	9.00
87	Samleshwari	(Check)	9.00
88	Shamjeera (Rajeev)	Not Available	9.00
89	UPR 2937-9-3-1	Not Available	9.00
90	Vandana	(Check)	9.00
91	Vishnu bhog (Rajeev)	Not Available	9.00
92	YN 3159-15-2	Not Available	9.00

* Plant damage score based on 0-9 scale.

*Average plant damage score based on 3 replications.

of N (1.703) in susceptible check TN1 while in resistant cultures N ranged from 1.213 to 1.587 per cent and this less reduction of nitrogen in resistant varieties indicated less depletion of proteins as compared to TN1. Such low depletion in resistant varieties might be due to lack of phago stimulatory amino acid in resistant variety against BPH as observed by Sogawa (1973).

4.2 Nymphal survival response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes

Out of 167 rice genotypes, 17 resistant genotypes including standard checks were selected to study the BPH nymphal survival. The nymphal survival test was carried out on 30 days old plant.

All these resistant genotypes exhibited average nymphal survival values varied from 46.00 to 74.00 per cent which was significantly lower than the susceptible check TN1 (Table 4.5), whereas developmental period values was ranged 11.38 to 17.68 days. 9 genotypes showed significantly higher developmental period than susceptible check TN1. In TN1 susceptible check variety nymphal survival value was maximum (90.00%) and corresponding developmental period was 11.33 days. The nymphal survival value was significantly lower in all the tested genotypes and Ptb33 than susceptible check TN. The results are represented in Fig 4.1.

Resistant check Ptb33 showed nymphal survival of 56.00 per cent, which was significantly higher than IR 78554-145-1-3-2, and R 1723-1413-3-357-1, genotypes but significantly lower than 5 genotypes *viz.* R1700-309-1-171-1, R1682-1997-61754-1, R1747-4941-1-515-1, R1700-304-1-161-1, R 1656-1146-5-513-1 and susceptible check TN1. Whereas, the developmental period on Ptb33 was 18.18 days, which was significantly higher than the all resistant genotypes excluding two genotypes and also than the susceptible check TN1. The genotype IR 78554-145-1-3-

Table 4.5: Percent nymphal survival and developmental period of BPH on selected resistant rice genotypes

Sr.No.	Designation	Nymphal survival (%)	Developmental period (days)	Growth index (GI)	Male %	Female %
1.	R1675-1844-2-1257-1	58.00 (49.67)	17.45	3.32	58.76 (50.30)	41.24 (39.70)
2.	R1723-1411-1-355-1	56.00 (48.51)	14.05	3.98	57.43 (49.51)	42.57 (40.49)
3.	R1723-1413-3-357-1	48.00 (43.85)	17.68	2.71	59.00 (50.31)	41.00 (39.69)
4.	R1682-1997-6-1754-1	64.00 (53.18)	13.72	4.66	52.38 (46.79)	47.62 (43.21)
5.	PBS RC 68	54.00 (47.31)	12.02	4.49	48.00 (43.85)	52.00 (46.15)
6.	R1605-315-131-1	54.00 (47.31)	13.64	3.95	44.00 (41.31)	56.00 (48.69)
7.	R1656-1146-5-513-1	62.00 (52.02)	11.38	5.44	44.00 (41.31)	56.00 (48.69)
8.	Indira Sugandhit Dhan 1	58.00 (50.67)	12.54	4.62	48.57 (44.18)	51.43 (45.82)
9.	R1688-2150-5-2060-1	58.00 (50.82)	12.54	4.62	43.90 (41.44)	56.10 (48.56)
10.	R1747-4941-1-515-1	64.00 (53.18)	12.46	5.13	43.81 (41.41)	56.19 (48.59)
11.	R1700-301-1-155-1	60.00 (50.82)	13.11	4.57	46.57 (43.03)	53.43 (56.98)
12.	R1700-304-1-161-1	64.00 (53.23)	14.47	4.42	44.86 (48.65)	55.14 (48.03)

13.	R1700-309-1-171-1	74.00 (59.45)	11.38	6.50	48.22 (43.98)	51.78 (46.02)
14.	IR78554-145-1-3-2	46.00 (42.69)	15.79	2.95	47.00 (43.38)	53.00 (46.62)
15.	IR81166-39-1-2-3	60.00 (50.82)	13.62	4.40	51.62 (45.80)	48.38 (44.20)
16.	PTB 33	56.00 (48.46)	18.18	3.08	60.66 (51.20)	39.34 (38.80)
17.	TN 1	90.00 (73.63)	11.33	7.94	35.22 (36.31)	64.78 (53.68)
	SEm±	2.08	0.43		3.87	3.87
	CD	5.87	1.23		10.93	10.93

- **Average of five replications**
- **Figures in the parenthesis are arc sin transformed values**

2 had the lowest nymphal survival (46.00%) followed by R 1723-1413-3-357-1 (48.00) which was significantly lower than the susceptible check TN1. The genotype 1723-1413-3-357-1 had the highest value of developmental period (17.68) days followed by R1675-1844-2-1257-1 (17.45) days and IR 78554-145-1-3-2 (15.79), which was also significantly higher than susceptible check TN1.

In all the resistant genotypes tested, the genotype R1700-309-1-171-1 had the highest nymphal survival value (74.00 %) followed by genotype R1682-1997-61754-1, R1747-4941-1-515-1, and R1700-304-1-161-1 (64.00%) but it was significantly lower than the susceptible check variety TN1. Among all the resistant genotypes tested, the genotype R1700-309-1-171-1 had the lowest developmental period value (11.38 days) followed by PBS RC 68 (12.02 days) and R1747-4941-1-515-1 (12.46 days), but it was not significantly different from susceptible check TN1.

Among all the resistant genotypes studied, the growth index (GI) values ranged from 2.71 to 6.50. The values show that in resistant check Ptb33 it was 3.08 and in susceptible check TN1 it was maximum i.e. 7.94. The results revealed that the genotype R1723-1413-3-357-1 had the lowest growth index (2.71) followed by IR 78554-145-1-3-2 (2.95) and R1675-1844-2-1257-1 (3.32). The genotype R1700-309-1-171-1 recorded the highest growth index (6.50) followed by the genotypes R 1656-1146-5-513-1 (5.44) and R1747-4941-1-515-1(5.13). In general all the resistant genotypes tested showed the lower growth index value as compared to susceptible check TN1.

The susceptible check TN1 showed the highest female population value (64.78%) and lowest male population (35.22%). The resistant check Ptb33 exhibited the female population value of (39.34%). The lowest population percent *i.e.* (41.00%) was observed in the genotype R1723-1413-3-357-1 followed by R1675-1844-2-1257-

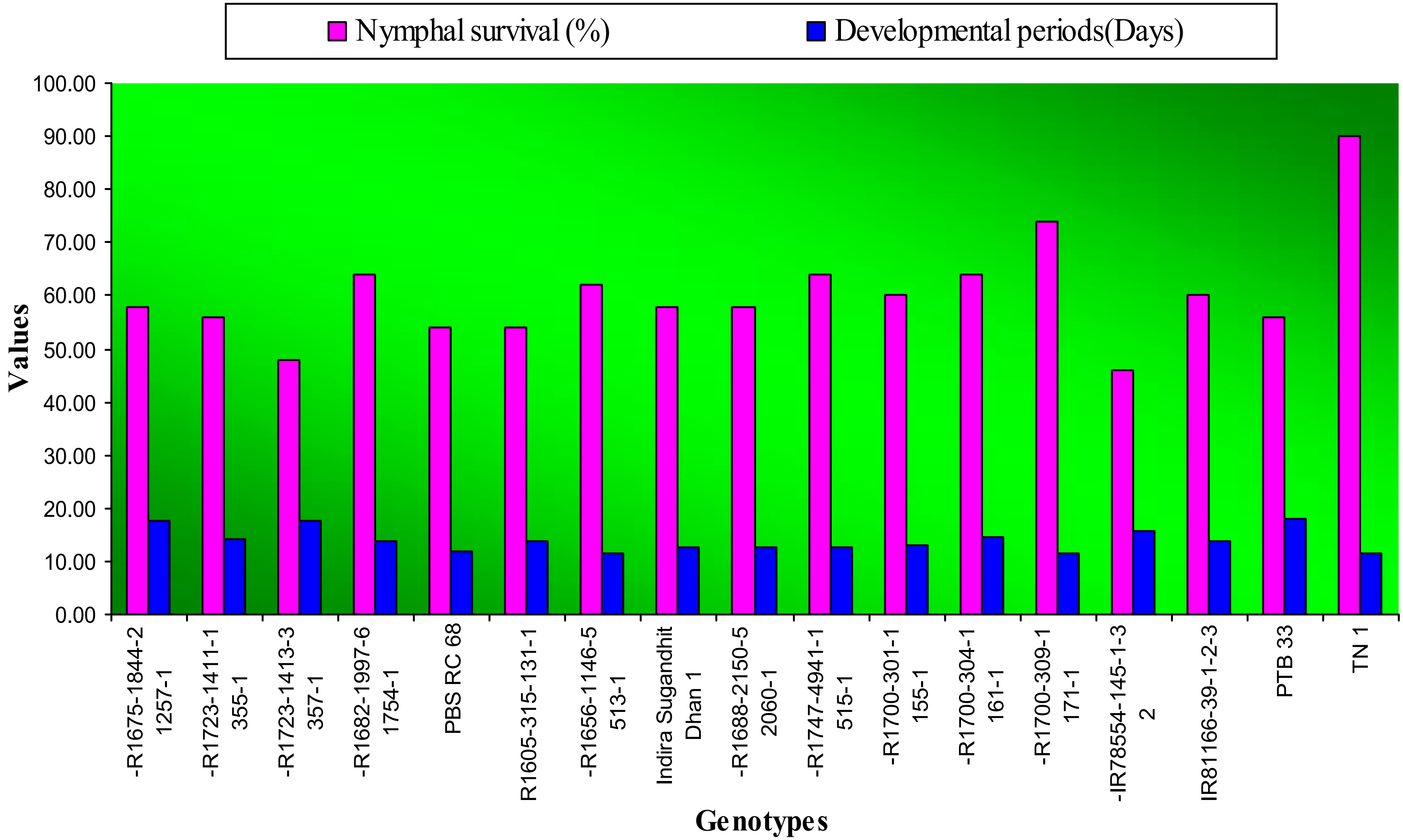


Fig.4.1: Nymphal survival and developmental periods of BPH on resistant rice genotypes

1 (41.24%), which were significantly inferior to susceptible check TN1 (90.00%). The highest male population percent was found in genotype R1723-1413-3-357-1 (59.00%) followed by R1675-1844-2-1257-1 (58.76) which were significantly higher than TN1.

Similar adverse effects on nymphal survival and prolongation of the nymphal period on resistant varieties have been reported by various scientists. The results were in conformity with the findings of several workers *viz*. Gao *et al*. (1990) investigated the brown planthopper survival on different rice varieties. They found that insect survival on Xiu-Shui 620 and IR64 was 50% of that on Xiu-Shui 48. Similarly, Senguttuvan *et al*. (1991) studied the relative impact of resistance mechanism antibiosis against *Nilaparvata lugens* in rice varieties under laboratory conditions. Antibiosis in Ptb33 and IR 64, the highly resistant and resistant varieties, was expressed as increased nymphal duration, decreased nymphal survival, while the reverse condition was noticed on the susceptible TN1.

Only small proportion of BPH nymphs develop as an adult when subjected to stay and fed on resistant variety. Velusamy *et al*. (1995) reported that the *N. lugens* caged on resistant wild rice had slow nymphal development as compared to *N. lugens* on cultivated resistant varieties.

Likewise, Nanda *et al*. (1999) found more nymphal survival on the susceptible control variety TN1 (82.0 to 92.0%) as compared with other varieties *viz*. Mudgo, ASD 7, Rathu Heenati, Babawee, ARC 6650, Utri Rajpan, Udaya, Pratap and Ptb33 (1.0 to 5.0%) at different crop ages. The reverse was however true as far as nymphal duration was concerned. The growth index was maximum on TN1.

Low nymphal survival and prolonged nymphal development on resistant genotypes/variety was also reported by Soundararajan *et al*. (2004), Reddy *et al*. (2005), Maheshwari *et al*. (2006), Alagar and Suresh (2007a) and Alagar *et al*. (2007).

Growth index of an insect provide the information on antibiosis mechanism of resistance. These indicated unsuitability of the resistant genotypes and suitability of the susceptible genotypes to BPH (Alagar and Suresh, 2007). The results showed that all the resistant genotypes recorded low growth index of BPH than the susceptible check TN1 and it was due to prolonged developmental period and low survival rate of nymphs. The genotype R1723-1413-3-357-1with lower growth index value (GI) 2.71 exhibited the high level of antibiosis. The lower growth index value in resistant genotypes was also reported by pioneer workers in the field of antibiosis viz. Soundararajan *et al*. (2003), Soundararajan *et al*. (2004), Alagar and Suresh (2007a) and Alagar *et al.* (2007). The susceptible variety favors the development of more females and vice versa.

The results on the reduction in the survival rate of BPH on resistant genotypes might be due to presence of antibiosis factors *i.e.* presence of feeding deterrents such as soluble salicic acid, malic acid, itaconic acid and benzoic acid in the resistant genotypes as reported by Soundararajan *et al*.(2002).

Results on the development of nymphs on the resistant genotypes suggested that the insect surviving on resistant genotypes had to face the problem of inadequate, unsuitable nutrition which may due to presence of higher total sugars and non reducing sugars. Greater nymphal survival, low developmental period on susceptible TN1 proved the availability of good quality food and reverse can be found in resistant genotypes.

Low level of total free amino acid and total starch content could be considered as the contributing factors in varietal resistance of the varieties to brown planthopper (Nanda *et al*., 2000). Zhang and Gu (1985) had determined the effects of various levels of certain amino acids in rice plants on the development of *Nilaparvata lugens* (Stal.) in laboratory studies at China. They stated that young nymphs, especially those in the 1st and 2nd instar, developed rapidly in the presence of adequate amounts of free tyrosine, glycine and lysine in rice plants. The concentrations of free glycine and lysine in plants were negatively correlated with nymphal survival rate.

4.3 Ovipositional response of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotypes

Out of 167 rice genotypes, 17 resistant genotypes including standard checks were selected to study the BPH ovipositional response. Low fecundity of BPH was observed on all resistant genotypes as well as on resistant check Ptb33 (Table 4.6) than TN1.

The number of eggs laid by BPH female on all the selected resistant genotypes ranged from 84.60 to 125.20 which is lower than susceptible check TN1 (154.20). The lowest fecundity of BPH was observed on the genotype R 1723-1413-3-357-1 (84.60) followed by R 1700-301-1-155-1 (89.00) and IR 78554-145-1-3-2 (93.20). The highest fecundity was observed in IR 81166-39-1-2-3 (125.20) followed by R1682-1997-6-1754-1 (121.60) and R1688-2150-5-2060-1 (116.2), while it was 80.40 and 154.20 on resistant check Ptb33 and susceptible check TN1, respectively. Results are represented in Fig 4.2.

The mean number of nymph emerged was significantly high in susceptible check TN1 (136.60), than all the tested genotypes and Ptb33. Among resistant genotypes the nymphal emergence value was ranged from 40.00 to 103.40. The resistant check Ptb33 had the nymphal emergence value of 29.80. The lowest number of nymph emergence was found in genotypes IR 78554-145-1-3-2 (40.00) followed by R 1723-1413-3-357-1 (41.40) and R 1700-301-1-155-1 (43.00), while it was higher in IR 81166-39-1-2-3 (103.40) followed by R1688-2150-5-2060- 1(91.40) and R1682-1997-6-1754-1 (87.00).

The mean number of unhatched egg varied from 21.80 to 53.20 among the resistant genotypes, whereas it was minimum (17.60) in susceptible check TN1 and maximum (50.60) in resistant check Ptb33. The highest number of unhatched eggs was found in the genotype IR 78554-145-1-3-2 (53.20) followed by R 1700-304-1-161-1 (48.80) and R 1700-301-1-155-1(46.00) and the lowest number of unhatched egg was found in the genotypes IR 81166-39-1-2-3 (21.80) and PBS RC 68 (24.40) followed by R1688-2150-5-2060-1 (24.80). All the resistant genotypes showed significantly higher number of unhatched eggs than the susceptible check TN1.

The percent unhatched eggs value was ranged from 17.41 to 57.08 per cent among all resistant genotypes, whereas it was 62.94 per cent and 11.41 per cent in resistant check Ptb33 and susceptible check TN1, respectively. The highest percentage of unhatched eggs was found in the genotype IR 78554-145-1-3-2 (57.08 %) followed by R1700-301-1-155-1 (51.69 %) and R1723-1413-3-357-1 (51.06 %). The genotype IR78554-145-1-3-2 showed the highest (70.72 %) reduced hatching over the susceptible check TN1 followed by R1723-1413-3-357-1 (69.69), while the genotype IR78554-145-1-3-2 showed the highest percent increase unhatching value over the susceptible check TN1 (66.92 %) followed by R1700-301-1-155-1 (61.74 %) and R1605-315-131-1 (59.45 %).

The results were matching with the findings of following pioneer scientists. Gao *et al*. (1990) studied the oviposition behaviour of brown planthopper on different

Table 4.6: Ovipositional response of BPH on selected rice resistant genotypes

Sr. no.	Designation	No. of nymph emerged	No. of unhatched eggs	fecundity (No.)	% unhatched eggs	% reduced hatching over TN-1	% increase unhatched over TN-1
1	R1675-1844-2-1257-1	61.20 (51.54)	38.20 (38.16)	99.4	38.43	55.2	53.93
2	R1723-1411-1-355-1	78.60 (62.74)	31.20 (33.86)	109.8	28.42	42.46	43.59
3	R1723-1413-3-357-1	41.40 (40.03)	43.20 (41.05)	84.6	51.06	69.69	59.26
4	R1682-1997-6-1754-1	87.00 (69.55)	34.60 (35.93)	121.6	28.45	36.31	49.13
5	PBS RC 68	85.60 (68.01)	24.40 (29.56)	110	22.18	37.34	27.87
6	R1605-315-131-1	56.40 (48.70)	43.40 (41.19)	99.8	43.49	58.71	59.45
7	R1656-1146-5-513-1	69.80 (56.81)	34.00 (35.62)	103.8	32.76	48.9	48.24
8	Indira Sugandhit Dhan 1	66.40 (54.65)	34.80 (36.12)	101.2	34.39	51.39	49.43
9	R1688-2150-5-2060-1	91.40 (73.68)	24.80 (29.82)	116.2	21.34	33.09	29.03
10	R1747-4941-1-515-1	61.40 (51.64)	40.20 (39.33)	101.6	39.57	55.05	56.22
11	R1700-301-1-155-1	43.00 (40.95)	46.00 (42.69)	89	51.69	68.52	61.74
12	R1700-304-1-161-1	49.20 (44.53)	48.80 (44.31)	106.8	27.53	43.34	40.14
13	R1700-309-1-171-1	68.60	40.20	108.8	36.95	49.78	56.22

		(56.01)	(39.33)				
14	IR78554-145-1-3-2	40.00 (39.18)	53.20 (46.85)	93.2	57.08	70.72	66.92
15	IR81166-39-1-2-3	103.40 (97.49)	21.80 (27.79)	125.2	17.41	24.3	19.27
16	PTB 33	29.80 (33.05)	50.60 (45.35)	80.4	62.94	78.18	65.22
17	TN 1	136.60 (126.98)	17.60 (24.70)	154.2	11.41	-	-
	SEm±	2.37	1.48				
	CD	6.67	4.18				

- **Average of five replications**
- **Figures in the parentheses are arc sine transformed values**

rice varieties. The mean numbers of eggs laid on varieties Xiu-Shui 620, Xiu-Shui 48 and IR64 were 191, 316.2 and 87.5 per female, respectively.

Results are matching with the finding of Reddy *et al.* (2005). Who studies plant resistance against BPH and reported that the hatchability of eggs was low in INRC 8815 and resistant check Ptb33. The egg hatchability was below 73 per cent in resistant genotypes and below 77 per cent in moderately resistant genotypes and was 95 per cent in susceptible check TN1.

The resistant genotypes Ptb33, ADT 45 and ASD 7 and the moderately resistant genotypes CO 43 and KAU 1661 recorded the more unhatched eggs compared with the susceptible genotype TN1,which was reported by Alagar *et al.* (2007a). Similarly, Alagar and Suresh (2007b) studied oviposition behavior of BPH, which showed that among the genotypes tested, ASD 16 recorded significantly lowest number of nymphal emergence (122.0 number/plant) which was 61.1 per cent lower than TN1 followed by Pusa Basmati (137.2), Jeeraga samba (143.2), ARC 10550 (146.6) and IR (150.6) which were at par with each other. Basmati 370 recorded significantly the highest percentage of unhatched eggs (25.4%) followed by ASD 16 (25.1 %) compared to TN1 which recorded the lowest value of 2.5 per cent.

Oviposition of BPH was significantly high on susceptible check TN1 and low on resistant genotypes as well as on resistant check Ptb33. All the resistant genotypes exerted adverse effect on the oviposition of BPH.

Lower rate of population build up on resistant genotypes was mainly due to the failure of eggs to undergo maturation (Sogawa and Pathak, 1970). Saxena and Pathak (1979) also observed reduced hatching of BPH eggs on resistant varieties than the susceptible varieties. Hatching is affected by probably because of the failure of developing larva to split the chorion *i.e.* the outer most layer of the eggs.

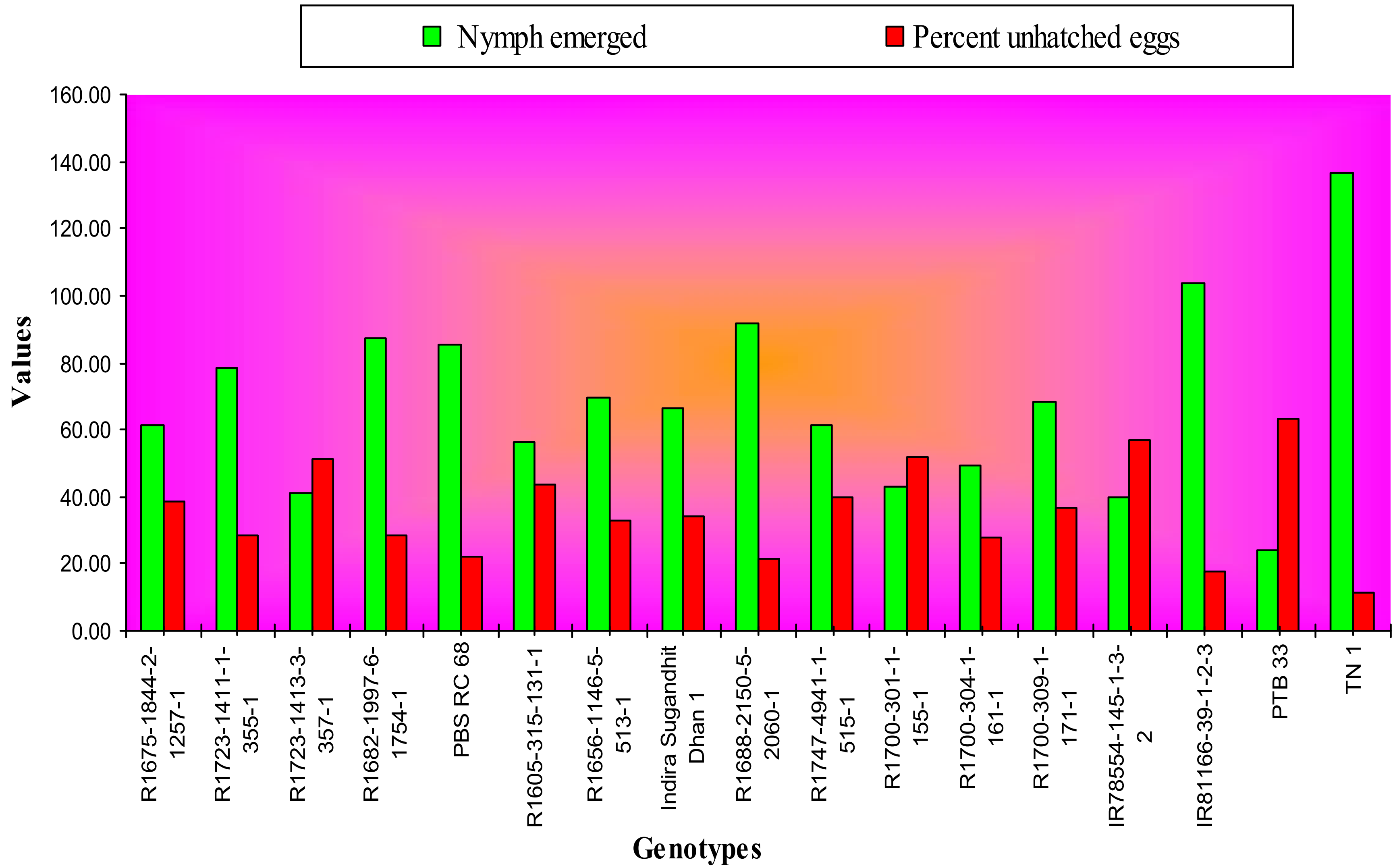


Fig 4.2: Ovipositional response of BPH on resistant rice genotypes

The cumulative effect of the insect developing on resistant genotypes with unbalanced nutrients reflected in poor oviposition rate on them. Comparatively lower nymphal emergence and low hatching of eggs were observed in resistant genotypes. This might be due to the chemical environment surrounding the developing eggs which affected the hatching by reducing the permeability of eggs (Alagar and Suresh, 2007a).

4.4 Probing mark test of brown planthopper *Nilaparvata lugens* (Stal.) on selected rice genotype

In all the selected resistant rice genotypes, the average probing marks per seedling were ranged from 20.50 to 34.88 and in resistant check Ptb33, the probe marks was 38.78 per seedling per female.

Out of the fifteen resistant rice genotypes tested, R1700-309-1-171-1 had the highest (34.88) average probing marks followed by R1700-304-1-161-1(34.25) and R1723-1411-1-355-1(32.00). Which was significantly higher than TN1 (Table 4.7). The resistant check rice genotype *i.e.* Ptb33 had the maximum number of probe marks (38.78) which was significantly higher than any other rice genotypes tested

Among all resistant genotype tested the genotype PBS RC 68 had the lowest average probing marks (20.50) followed by R1747-4941-1-515-1 (24.50) per seedling.

The lowest average probing marks per seedling (11.80) was observed in susceptible check TN1. Statistically numbers of probes received by all resistant genotypes tested were significantly high as compared to susceptible check TN1. Similarly several workers like Sogawa and Pathak (1970), Veronica (1985), Reddy (1979) and Reddy and Kalode (1985) indicated that the resistant varieties receive more number of probing punctures than susceptible ones. Bagui (1989) reported that

Table 4.7: Probing mark of on resistant rice genotypes against BPH

Sr. No.	Designation	Average probing marks
1	R1675-1844-2-1257-1	28.00 (31.81)
2	R1723-1411-1-355-1	32.00 (34.36)
3	R1723-1413-3-357-1	29.20 (32.61)
4	R1682-1997-6-1754-1	29.62 (32.91)
5	PBS RC 68	20.50 (26.61)
6	R1605-315-131-1	28.87 (32.36)
7	R1656-1146-5-513-1	25.63 (30.30)
8	Indira Sugandhit Dhan 1	31.80 (34.09)
9	R1688-2150-5-2060-1	27.22 (31.29)
10	R1747-4941-1-515-1	24.50 (29.62)
11	R1700-301-1-155-1	27.30 (31.45)
12	R1700-304-1-161-1	34.25 (35.81)
13	R1700-309-1-171-1	34.88 (36.16)
14	IR78554-145-1-3-2	30.11 (33.16)
15	IR81166-39-1-2-3	28.22 (32.01)
16	PTB 33	38.78 (38.47)
17	TN 1	11.80 (20.01)
	SEm±	1.17
	CD	3.28

****Average of ten replications**

Figures in the parentheses are arc sine transformed value

adult brachypterous females of *Nilaparvata lugens* made more probing marks on resistant variety. Lu *et al.* (1999) reported the probing behavior of different biotypes of *Nilaparvata lugens* on TN1 (susceptible variety) and ASD 7 (resistant variety). The probing frequency of biotype 1 on TN 1 decreased significantly, and that of biotype 3 on ASD 7 increased significantly.

The probing marks behaviour of BPH on 23 selected resistant rice donors studied by Rana and Dubey (2010). The probing marks ranged from 13.10 to 25.10 which was significantly higher than susceptible check TN1 (10.33). Therefore, it is crystal clear that susceptible host received less probe marks due to easier penetration of insect stylets as well as the adequate host suitability to the insect, whereas, in resistant host the more probe marks are the indication of unsuitability to the insect thereby insect exerting the extra efforts in quest of it. The resistant genotypes probably contain feeding deterrent, thereby restricted feeding activity by BPH, consequently the numbers of probes were also found increased. If nutritional requirement of insect was not fulfilled, insect did not continue to feed on host plant so in such genotypes there might be feeding deterrent like high phenol presence, which probably play the main factor to restrict the feeding of BPH on host plant.

It is very clear that susceptible host has received less probe marks because of the presence of required nutritional value, or the absence of harmful biochemical's in the plant itself, whereas, in resistant host the more probe marks might be the indication of unsuitability of nutrition in the plant or presence of certain plant biochemical's which checks the feeding and proves the presence of mechanism of resistance.

Summary, Conclusion and Suggestions for Future Research Work

CHAPTER -V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Summary

The present study entitled **"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes"** was carried out at Glass House, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during 2012-2013. The results obtained in the present investigation are summarized as under:

In the present study, one hundred sixty seven rice genotypes were evaluated against *Nilaparvata lugens* (Stal.). Among these 167 rice genotypes, 39 genotypes are categorized, while 24 as moderately resistant, 12 as moderately susceptible and 92 genotypes susceptible to BPH.

Study in terms of nymphal survival revealed that the genotype IR78554-145-1-3-2 had the lowest nymphal survival (46.00%) followed by R 1723-1413-3-357-1 (48.00) which was significantly lower than the susceptible check TN1, whereas the genotype R1700-309-1-171-1 had the highest nymphal survival value (74.00 %) followed by genotype R1682-1997-6-1754-1 (64.00 %). The lowest growth index value was found in the genotype R1723-1413-3-357-1which had the growth index value (2.71) followed by IR 78554-145-1-3-2 (2.95), while highest GI value was in R1700-309-1-171-1 (6.50) followed by R1656-1146-5-513-1 (5.44).

The insect population with female and male were not significantly different in all the rice genotypes including resistant and susceptible check Ptb33 and TN.

The ovipositional effect of different genotypes on BPH was observed on 30 days old plants. The lowest number of nymphal emergence was found in genotypes IR

78554-145-1-3-2 (40.00) followed by R 1723-1413-3-357-1 (41.40) and R 1700-301-1-155-1 (43.00), while it was higher in IR 81166-39-1-2-3 (103.40) followed by R1682-1997-6-1754-1 (87.00) and PSB RC 68 (85.60). The highest number of unhatched eggs was found in the genotype IR 78554-145-1-3-2 (53.20) followed by R1700-304-1-161-1 (48.80) and R1700-301-1-155-1(46.00) and the lowest number of unhatched egg was found in the genotypes IR81166-39-1-2-3 (21.80) and PBS RC 68 (24.40) followed by R1688-2150-5-2060-1 (24.80). The highest percentage of unhatched eggs was found in the genotype IR78554-145-1-3-2 (57.08 %) followed by R1700-301-1-155-1 (51.69 %) and R1723-1413-3-357-1 (51.06 %). The genotype IR78554-145-1-3-2 showed the highest 70.72 per cent reduced hatching over the susceptible check TN1 followed by R1723-1413-3-357-1(69.69%) and Ptb33 (78.18%), while the genotype IR78554-145-1-3-2 showed the highest percent increase unhatching value over the susceptible check TN1 (66.92 %) followed by R1700-301-1-155-1 (61.74 %) and R1605-315-131-1 (59.45 %).

Probing marks were observed at 7 days old seedlings. The highest probing marks per seedling i.e. 34.88 was found in resistant genotype R1700-309-1-171-1 followed by R1700-304-1-161-1(34.25). The minimum average probing marks per seedling (11.80) was found in genotypes TN1 followed by PBS RC 68 (20.50). Significantly higher number of probing marks was found in all resistant genotypes as compared to susceptible check TN1.

Conclusion

Out of all resistant genotypes tested for nymphal survival of BPH, the genotype IR 78554-145-1-3-2 had the lowest nymphal survival value (46.00%) with the least growth index value 2.71, which showed the highest degree of resistance. It is confirmation that this genotype is not favorable for the development of nymphs.

Among all the resistant genotypes tested, the genotype R1723-1413-3-357-1 had the lowest female sex population and highest male population followed by R1675-1844-2-1257-1 and R1723-1411-1-355-1 it is also due to the effect of host plant interaction with BPH. The more number of females emerge out on the susceptible check due to suitability of the host plant for feeding and reverse can be seen in resistant genotypes.

The lowest number of nymph emergence was found in genotype IR78554-145-1-3-2 (40.00) followed by R R1723-1413-3-357-1 (41.40) and R1700-301-1-155-1 (43.00) and the highest number of unhatched eggs was found in the genotype IR78554-145-1-3-2 (53.20) followed by R1700-304-1-161-1 (48.80) and R1700-301-1-155-1 (46.00). This is due to strong antibiosis present in these genotypes which exerted the adverse effect on the normal biology of the insect resulting in reduced hatching of eggs and lower nymphal emergence. In another words we can say that the mortality of developing embryos within the eggs is due to presence of certain biochemicals surrounding the eggs.

The highest percentage of unhatched eggs was found in the genotype IR78554-145-1-3-2 (57.08 %) followed by R1700-301-1-155-1 (51.69 %) and R1723-1413-3-357-1 (51.06 %) this is due to the higher proportion of unhatched eggs and lower fecundity.

Due to unsuitability of host plant for the number of probes received by all resistant genotypes were significantly higher than the susceptible check TN1, which indicates the presence of probe deterrents in these rice genotypes. The variability in reaction pattern of host plant among themselves might be due to the presence of certain biophysical and biochemical factors which restricts the probing of BPH on these genotypes.

Suggestion for future research work

1. The rice genotypes tested against the pest in laboratory should also be tested in field condition to realize its impact against the pest in presence of biotic and abiotic factors.
2. Study of BPH resistant genotypes at biochemical level will focus on the actual cause of host plant resistance.
3. Gene responsible for resistance to BPH and also for synthesis of plant substances like phenol, amino acids, sugar, feeding deterrents, sterols etc. should be find out by using biotechnology technique.
4. Breeding programmes can be initiated to alter the biochemical attributes of host to impart antibiosis mechanism of resistance against the pest.

Abstract

"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes"

By

SERVEN KUMAR VERMA

ABSTRACT

The present investigation entitled **"Brown planthopper, *Nilaparvata lugens* (Stal.) donors validation test on evaluated rice genotypes"** was carried out in the Glass House, Department of Entomology, College of Agriculture, IGKV, Raipur (C.G.) during 2012-2013.

One hundred sixty seven rice genotypes were screened against *Nilaparvata lugens*, among the screened material 39 genotypes were categorized as resistant, whereas 24 as moderately resistant and rest of the other as moderately susceptible and susceptible to BPH. Among all the genotypes screened, the genotype R 1723-1413-3-357-1 had the least plant damage score (1.03) followed by R 1688-2077-1-262-1(1.04) due to BPH infestation.

The study in terms of nymphal survival revealed that the lowest percent of nymphal survival i.e. only 46.00 per cent in resistant genotype R78554-145-1-3-2, while highest i.e. 90.00 per cent in susceptible check TN1. Likewise the insect becomes adult rapidly in susceptible check TN1 with 11.33 days mean developmental period, while it take more time to become adult as 17.68 days in resistant genotype R 1723-1413-3-357-1, which are the indication of resistance mechanism in the host.

Among different genotypes tested for their ovipositional effect on BPH, the genotype R1723-1411-2-356-1 had the lowest number of nymphal emergence (40.00) along with the highest number of unhatched eggs (53.20), whereas highest nymphal emergence (136.60) and very low number of unhatched eggs (17.60) was found in susceptible check TN1. Among tested resistant genotypes, PSB RC 68 showed the least numbers of probes *i.e.* 20.50 followed by R1747-4941-1-515-1 (24.50), while it was very low in susceptible check TN1 i.e. (11.80).

College of Agriculture,
Dept. of Entomology

Major Advisor
(Dr. D.K. Rana)

References

REFERENCES

Alagar, M. and Suresh, S. 2007a. Antibiosis mechanism of resistance to brown plant hopper, *Nilaparvata lugens* (Stal.) on selected rice genotypes. *Ann. Pl.Protc.Sci.* 15 (2): 283-286.

Alagar, M. and Suresh, S. 2007b. Settling and ovipositional preference of *Nilaparvata lugens* (stal.) on selected rice genotypes. *Ann.Pl.Protc.Sci.* 15 (1): 43-46.

Alagar, M., Suresh, S., Samiyappan, R. and Saravanakumar, D. 2007. Reaction of resistant and susceptible rice genotypes against brown planthopper (*Nilaparvata lugens*). *Phytoparasitica* 35 (4):346-356.

Alam, S.N. and Cohen, M.B. 1998. Detection and analysis of QTLs for resistance to brown planthopper, *Nilaparvata lugens*, in a double-haploid rice population. *Theor. Appl. Genet*. 9:1370–1379.

Alarn, S.N. and Cohen, M.B. 1998. Durability of brown planthopper, *Nilaparvata lugens*, resistance in rice variety IR64 in greenhouse selection studies. *Entomol. Exp. Appl.* 89: 71-78.

Alexandratos, N., Bruinsma, J. and Boedeker, G. 2006. *World Agriculture: Towards 2030/2050*. Interim Report. Prospects for Food, Nutrition, Agriculture and Major Commodity Groups. Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations.

Anonymous, 1981. International Rice Research Institute, Annual Report, Los Banos, Phillippines.Pp.116-131.

Anonymous, 1996. Standard Evaluation System, IRRI, Philippines.

Anonymous, 1999. Host plant resitance: Brown planthopper. DRR *Annual Report*. Pp.64-67.

Anonymous, 2002. Host plant resistance: Brown planthopper. DRR *Annual Report*. Pp.75-77.

Anonymous, 2007. Directorate of Economics and Statistics Survey Govt.of India. Ministry of Finance, Economic Division, New Delhi. Pp.14-15.

Anonymous, 2010. FAO Rice Market Monitor Trade and market division Food and Agriculture Organization of the United Nations.

Anonymous, 2011. Indira Gandhi Krishi Vishwavidyalay, Raipur, Krishi Diary. C.G.Pp.1.

Bagui, M.A. 1989. Feeding aspect of rice brown planthopper *Nilaparvata lugens* (Stal.) (Homoptera: Delphacidae). Bangladesh *J. Zool.,* 17(2): 143-147.

Bai, N.R., Nair, S.S., Devika, R., Revina A., Leena Kumary, S., Radhadevi, D.S. and Joseph, C.A. 1992. Brown planthopper (BPH) resistant varieties developed at Monosompu, Kerala. *Int. Rice Res. Newls.* 17(4):10-14.

Bhattacharyya, P.R., Bhattacharyya, A.K. and Verma, S.K. 1983. Reaction to some rice germplasm to planthopper and Hyderabad population of Brown planthopper *Nilaparvata lugens* (Stal.). *Indian J. Ent*., 45 (2): 108-119.

Bhimrao, K.G., Dubey, V.K. and Pophaly, D.J. 2005. Studies on relative degree of damage by Brown planthopper *Nilaparvata lugens* (stal.) on rice genotype and its management through plant derivatives. *M.Sc. (Ag.) Thesis,* IGKV, Raipur. Pp. 45.

Chen, C.N. and Cheng, C.C. 1978. The population level of *Nilaparvata lugens* (Stal) in relation to yield loss of rice. *Plant Protec. Bull.* (Taiwan) 20: 197-209.

Diehl, S. R. and Bush, G. L. 1984. An evolutionary and applied perspective of insect biotypes. *Ann. Rev. Entomol*. 29: 471−504.

Du, P.V. 2007. Yellowing syndrome of rice: Etiology, current status and future challenges. *Omon rice* 15: 94–101.

Dyck, V.A. and B. Thomas. 1979. The brown planthopper problem. *In International Rice Research Institute*, Pp. 3-17.

Gangrade, G.A., Kaushik, U.K., Patidar, G.L., Shukla, B.C., Shrivastava, S.K., Deshmukh, P.D. and Pophaly, D.J. 1978. Insect pest of summer paddy in M.P, India. *International. Rice Research. Newsl.* 3(6):16.

Gao Chunxian, Bai Yawei, and Gu Xiuhui. 1992, Some resistance indices of selected sesistant japonica varieties to Rice Brown Planthopper *J.* 6 (3): 125-130.

Gao, C.A., Gu, X.H. and Bei, Y.W. 1990. Antibiosis and evaluation of the resistance of Xiu-Shui 620 to the brown planthopper, *Nilaparvata lugens*. *Chinese Journal of Rice Science* 4 (4): 175-180.

Harini, A.S., Lakshmi, S.S., Kumar, S.S., Sivaramakrishnan, S. and Kadirvel, P. 2010. Validation and fine-mapping of genetic locus associated with resistance to brown plant hopper *Nilaparvata lugens* (Stal.) in rice *Oryza sativa* L. *Asian Journal of Bio Science* 5(1): 32-37.

Hattori, M. and Sogawa, K. 2002. Oviposition Behavior of the Rice Brown Planthopper, *Nilaparvata lugens* (Stal.), and its electronic monitoring; 15 (11): 283-29.

Heinrichs, E.A. and Mochida, O. 1984. From secondary to major pest status: The case of insecticide-induced rice brown planthopper, *Nilaparvata lugens* resurgence. *Prot. Ecol.* 7:201–218.

Heinrichs, E.A., Medrano, F.G., Rapusas, H.R., Yega, C., Medina, E., Ramena, A., Viajante, V., Sunio, I., Demiongo, E. and Camang, E. 1985. Insect pest resistance of IR 5 to IR 62. *Int. Rice Res. News.* 10 (6): 12-13.

Jena, K. K. and Kim SukMan 2010. Current status of brown planthopper (BPH) resistance and genetics. *Journal article.* 3: 161-171.

*Kalode, M.B., Krishna, T.S. and Gour, T.B. 1979. Studies on pattern of resistance to brown planthopper (*N. lugens*) in some rice varieties. *Pro. Ind. Nat. Sc. Acad. B*-44: 43-48.

Kawabe, S., Mclean, D. L., Tatsuki, S. and Ouchi, T. 1981. An improves electronic measurement system for studying ingestion and salivation activities of leafhopper. *Ann. Entomol. Soc. Am*. 74: 222-225.

Khinkhin, M. M., Masaya, M., Masami, T. and Hideshi, Y. 2009. Demographic Parameters of Long–term Laboratory Strains of the Brown Planthopper, *Nilaparvata lugens* Stal. (Homoptera: Delphacidae) on Resistance Genes, bph20 (t) and Bph21 (t) in Rice. *J. Fac. Agr., Kyushu Univ.* 54 (1):159–164.

Khush, G.S. 1979. Genetics of resistant and breeding for resistance to the brown planthopper, *In International Rice Research Institute* Pp. 321-332.

Kisimoto, R. 1960. The hopper burn injury formation of rice brown planthopper. *Jap. J. Plant Prot.*14: 377-382.

Krishna T. S., Seshu D. V. and Kalode M. B. 1977. New Sources of Resistance to Brown Planthopper of Rice *Indian Journal of Genetics and Plant Breeding* 37: 147-153.

Krishnaiah, K., Reddy, A.P.K., Krishnaiah, N.V.and Pasalu, I.C. 1999. Current problems and future needs in plant protection in rice. *Indian J.Plant Protection* 27 (1&2): 47-64.

Kulshreshtha, J.P., Anjaneyulu, A. and Padmanabhan, S.Y. 1974. A disastrous brown planthopper attack in Kerala. *Indian Farming* 24, (9):5-7.

Kumar, R., Managanvi, K. and Tiwari, S.N. 2012. Screening of Rice varieties resistant against Brown Planthopper, *Nilaparvata Lugens* (Stal.) *Bio. infolet* 9: 730-731.

Kumar, H., Maurya, R. P. and Tiwari, S. N. 2012. Study on antibiosis mechanism of resistance in rice against Brown Planthopper, *Nilaparvata lugens* (Stal.). *Annals of Plant Protection Sciences* 20. Pp.98.

Ling, K.C., Tiongco, E.R. and Aguiero, V.M. 1978. Rice ragged stunt, a new virus disease. *Plant Dis. Rep* 62: 701-705.

Liu, Z.W. Han, Z.J., Zhang, L.C. and Wang, Y.C. 2002. A method for raising brown planthopper (BPH) *Nilaparvata lugens* (Stal.) *IRRN* 10 (1): 11.

Lu, Z.X., Yu, X.P., Xie, Z.P., Chen, J.M. and Zeng, X.S. 1999. The different feeding and oviposition behaviour among brown planthopper biotypes. *Acto Phytophylacia since* 26(3): 203-207.

Maheshwari, M.U., Suresh, S. and Emmanuel, N. 2006. Evaluation of mechanisms of resistance in conventional and hybrid rice varieties against *Nilaparvata lugens* Stal. *Ann.Pl. Protc. Sci*.14 (2): 319-322.

Majumdar, N. 1980. Mass rearing of brown planthopper. *CRRI Annual Report*, 1979. Central Rice Research Institute, Cuttack, India. Pp.176-177.

Manjunath, T. M., 1977. A note on oviposition in the macropterous and brachypterous forms of the rice brown planthopper, *Nilaparvata lugens* Stal. (Homoptera, Delphacidae). *Journal of Insect Behavior* 86: 405-408.

Mathur, K.C., Reddy, P.R., Rajamani, S. and Moorthy, B.T.S. 1999.Integrated pest management in rice to improve productivity and sustanibility. *Oryza* 36 (3): 195-207.

Mochida, O. 1977.Taxonomy and biology of *Nilaparvata lugens* (Homoptera: Delphacidae).Brown planthopper symposium. *International Rice research Institute, Los Banos, Philippines*. pp. 55.

Mullins, I.M. 1999. Evolutionary Relationships in Oryza Inferred from the Gene that Encodes the 10 kDa Prolamin (Seed Storage Protein) Polypeptide. Master's of Science In Biology. Faculty of the Virginia Polytechnic Institute and State University.

Nalini K.,T. and Mammen, K.V. 1975. Biology of the brown planthopper (*Nilaparvata lugens* Stal.) (Delphacidae: Homoptera). *Agricultural Research Kerala* 13 (1):53-54.

Nanda, U.K., Dash, D. and Rath, L.K. 1999. Antibiosis in some rice varieties to the brown planthopper, *Nilaparvata lugens* (Stal.). *Pest Management and Economic Zoology* 5 (2): 101-105.

Nanda, U.K., Dash, D. and Rath, L.K. 2000. Biochemical basis of resistance in rice to the brown planthopper *Nilaparvata lugens. Ind.J.Ent* 62 (3): 239-241.

Nasu, S. 1964. Taxonomy, distribution, host range, life cycle and control of rice leaf hoppers. Major insect pest of rice *plant. Proc. Symp. IRRI*, Los Banos, Phillippines. Pp.493-523.

*Natio, A. 1964. Methods of detecting feeding marks of leaf and planthopper and its application. *Plant Prot. Japan.* 18 (12): 482-484.

Nguyen, N. and Ferrero, A. 2006. Meeting the challenges of global rice production. *Paddy and Water Environment* 4(1):1-9.

Okada, T., 1977. Taxonomic characters of identification of the rice brown pianthopper *Nilaparvata lugens* and its related species in the Asian and Pacific region. In: The Rice Brown Pianthopper. ASPAC, Taiwan, Pp. 1-23.

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. and Saxena, R.C. 1980. Breeding approaches in rice breeding plant resistance to insects. John Wiley, New York. Pp.422-456.

Pongprasert, S. and Weerapat, P. 1979. Varietal resistance to the brown planthopper in Thailand. Pp. 273– 284.

Ponnada, U., Pophaly, D.J., Shaw, S. S., and Ganguli, J.L., 2011. Feeding and Probing Behaviour of Rice Brown Planthopper (BPH) *Nilaparvata Lugens* (stal.) Department of Entomology, *Indian Journal of Entomology* 73: 201-203.

Pophaly, D.J. and Rana, D.K. 1994. Virulence in *Nilaparvata lugens* (Stal.) population of Raipur to rice. *Oryza* 31: 301-304.

Pophaly, D.J., Gupta, A.K., Rana, D.K. and Verma, V.K. 2001. Biological and genetic analysis of rice germplasm with resistance to brown planthopper in the collection of Indira Gandhi Agricultural University. Rice Research for food security and poverty alleviation proceeding of the International Rice research Conference, Los Banos, Phillippines. Pp. 401-409.

Rana, D.K. and Dubey V.K. 2010. Evaluation of rice accessions for resistance to brown planthopper *Nilaparvata lugens* (Stal.). *Journal of Soil and Crops* 20 (1) 22-24.

Reddy, K.L. Pasalu, I.C., Sreenivasa, A.R. and Reddy, D.D.R. 2004. Biochemical basis of resistance in rice cultivars to brown planthopper *Nilaparvata lugens* (Stal.) *J. Ent. Res.* 28 (1): 79-85.

Reddy, K.L., Pasalu, I.C. and Reddy, D.D.R. 2005. Studies on antibiosis mechanism of resistance in rice against brown planthopper, *Nilaparvata lugens* (Stal.). *Ind. J. Ent*. 67(2): 140-143.

Reddy, K.V. and Kalode, M.B. 1985. Mechanism of resistance in rice varieties showing differential reaction to brown planthopper. *Proc. Indian. Acad. Sci. (Anim. Sci.)*. 94: 37-48.

Reddy, K.V.1979. Varietal resistance to brown planthopper *Nilaparvata lugens* (Stal). In rice. M.Sc. (Ag.) *Thesis.* Andhra Pradesh Agricultural University, Hyderabad. Pp.110.

Rivera, C.T., Ou, S.H. and Lida, T.T. 1966. Grassy stunt disease of rice and its transmission by *Nilaparvata lugens* (Stal). *Plant Dis. Rep*. 50: 453-456.

Sable, M. G. 2010. Host plant resistance to Brown planthopper, *Nilaparvata lugens* (Stal.) on selected rice genotypes with special reference to antibiosis traits. *M.Sc. (Ag) Thesis*, IGKV C.G., Pp. 42-78.

Santhanalakshmi, S., Saikumar, S., Rao, S., Saiharini, A., Khera, P., Shashidhar, H.E. and Kadirvel, P. 2010. Mapping genetic locus linked to brown planthopper resistance in rice *Oryza sativa* L. *Int. J. Plant Breed*. *Gene*. 4:13-22.

Satpathi C. R., Katti ,G. and Prasad, Y. G. 2011. Effect of Seasonal Variation on Life Table of Brown Plant Hopper *Nilaparvata lugens* Stal. on Rice Plant in Eastern India, *East Journal of Scientific Research* 10 (3): 370-373.

Saxena, R.C. and Pathak, M.D. 1979. Factors governing susceptibility and resistance of certain rice varieties to the brown planthopper. In: Brown planthopper: Threat to rice production in Asia, International Rice Research Institute, Philipines. Pp.303-317.

Senguttuvan, T., Gopalan, M. and Chelliah, S. 1991. Impact of resistance mechanisms in rice against the brown planthopper, *Nilaparvata lugens* Stal. (Homoptera: Delphacidae). *Crop Protc.* 10 (2): 125-128.

Seo, B.Y., Jung, J.K., Choi, B.R., Park, H.M. and Lee, B.H. 2009. Resistance-breaking ability and feeding behavior of the brown planthopper, *Nilaparvata lugens*, recently collected in Korea International Rice Research Institute. Pp. 303-314.

Shen, J.H., Mao, X.Q., Sun, G.C., Liu, G.J. and Cheng, S.H. 2002. Identification of the resistance of super-rice cultivars (elite lines) to diseases and insect pests. *Pl. Protc*. 28 (3): 9-11.

Shuguang, H., Xianian, C. and Xiaoxi, Z. 2000. Effects of nine rice varieties on survival and oviposition of *nilaparvata lugens* (Sta.). *Journal of Nanjing Agricultural University* 23(2): 39-42.

Siddegowda, D.K. 2009. Screening of rice germplasm against brown planthopper, *Nilaparvata lugens* (Stal.). Annual meeting Entomology, University of agricultural sciences, Bangalore, Mandya, Karnataka, India. Pp 170-173.

Singh, J. S., Yolanda, H. C., Kadirvel, P., Gary, C. J., Maheswaran, M., Candida, B.A. and Hei, L. 2008. Categories and Inheritance of Resistance to *Nilaparvata lugens* (Hemiptera: Delphacidae) in Mutants of Indica Rice IR64 *J. Eco. Ento*. 101 (2): 575-583.

Sogawa, K. 1973. Feeding behaviour of the brown planthopper and brown planthopper resistance of indica rice mudgo, Bull No. 4. Laboratory of Applied Entomology, Faculty of Agriculture, Nagoya University. Pp. 151.

Sogawa, K. and Pathak, M.D. 1970. Mechanism to brown planthopper resistance to Mudgo variety of rice (Hemiptera : Delphacidae). *Appl. Ent. Zool*. 5: 145-158.

Soundararajan, R.P., Chitra, N. and Gunathilagaraj, K. 2002. Evaluation of antibiosis resistance to brown planthopper, *Nilaparvata lugens* Stal. in rice. *J. of Appl. Zool. Res*.13 (1): 14-18.

Soundararajan, R.P., Chitra, N. and Gunathilagaraj, K. 2003. Antibiosis effect of rice double haploid lines on growth and adult longevity of brown planthopper, *Nilaparvata lugens* (Stal.). *Ind. J. Pl. Protc*. 31 (1): 154-156.

Soundararajan, R. P., Kadirvel, P., Gunathilagaraj, K. and Maheswaran, M. 2004. Mapping of Quantitative Trait Loci Associated with Resistance to Brown Planthopper in Rice by Means of a Doubled Haploid Population. *Crop Sci*. 44: 2214–2220.

Su, C. C., Zhai, H. Q., Wang, C.M., Sun, L.H. and Wan, J.M. 2006. SSR Mapping of brown plant hopper resistance gene Bph9 in Kaharamana, an Indica rice (*Oryza sativa* L.). *Acata Genetica Sinica* 33 (3): 262-268.

Sujatha, G., Reddy, G.P.V. and Murthy, M.M.K. 1987. Effects of certain biochemical factors on the expression of resistance of rice varieties to brown planthopper *Nilaparvata lugens*. *Journal of research APAU*. 15:124-128.

Tester, M., and Langridge, P. 2010. breeding technologies to increase crop production in a changing world. Science (New York). 327: 18-22.

Timmer, C.P. Pandey, S., Byerlee, D., Dawe, D., Dobermann, A., Mohanty, S., Rozelle, S. and Hardy, B. 2010. Rice in the global economy: *strategic research and policy issues for food security*. Los Banos (Philippines): International Rice Research Institute. Pp. 37-59.

Tripathi, D. 2012. Evaluation of rice genotypes for resistance to brown planthopper, *Nilaparvata lugens* (Stal.) MSc (Ag) *Thesis,* I.G.K.V. Raipur C.G. Pp 53.

Urre, M.S., Dubey, V.K. and Pophaly, D.J. 2004a. Screening of promising rice genotypes against brown planthopper *Nilaparvata lugens* (Stal.). In: *International Symposium on Rainfed Rice Ecosystems*: Perspective and Potential. Pp.190.

Urre, M.S., Dubey, V.K., Rana, D.K. and Yadu, Y.K. 2004b. Comparative feeding capacity of *Nilaparvata lugens* (Stal.) on resistant, moderately resistant and susceptible rice genotypes. *In*: *International symposium on rainfed rice ecosystems: perspective and potential.* 11-13 October, 2004. Pp.190.

Vanitha, K., Suresh, S., Maheswaran, M. 2011 Nature of Plant Resistance in Recombinant Inbred Lines of Basmati 370/Asd16 Cross to Rice Brown Planthopper (*Nilaparvata Lugens* Stal.) *Annals of Plant Protection Sciences* 19: Pp. 261.

Velusamy, R. 1991. Resistance of breeding lines derived from *Oryza officinalis* to brown planthopper (BPH). *Int. Rice Res. Newls* 16 (1): 14.

Velusamy, R., Ganesh Kumar, M. and Johnson Edward, Y.S. 1995. Mechanism of resistance to brown planthopper *Nilaparvata lugens* in wild rice (*Oryza spp*) cultivars. *Entomol. Exp. Appl.* 74 (3):245-251.

Velusamy, R. and Heinrichs, E.A. 1986. Electronic Monitoring of feeding behaviour of *Nilaparvata lugens* (Homoptera: Delphacidae) on resistant and susceptible rice varieties. *Enviorn. Ent*. 15: 678-682.

Veronica, B.K. 1985. Studies on multiple resistance to leaf and planthopper in rice varieties. Ph.D. *Thesis*, Osmania University, Hyderabad, India Pp .110.

Wada, T., Ito, K., Takahashi, A. and Tang, J. 2007. Variation of preovipositional period in the brown planthopper, *Nilaparvata lugens*, collected in tropical, subtropical and temperate Asia. *J. Appl. Entomol.* 131: 698–703.

Watanabe, T. and Kitagawa, H. 2000. Photosynthesis and translocation of assimilates in rice plants following phloem feeding by the planthopper *Nilaparvata lugens* (Homoptera: Delphacidae) *Journal of Economic Entomology* 93: 1192-1198.

Whalon, M.E., Van De Baan, H.E. and Untung.1990. Resistance management of Brown planthopper, *Nilaparvata lugens* in Indonesia. *Pest management in Rice*, eds. B. T. Grayson, M.B. Green, L. G. Copping, London.Pp 303-309.

Woodhead, S. and Padgham, D.E. 1988. The effect of plant surface characteristics on resistance of rice to brown planthopper. *Nilaparvata lugens*. *Ent. Exp. Appl.* 27: 149-155.

Xiaolin, D., Yifan, Z., Jianqing, Z., Zhong X., S., Jing, C., Jie, C. and Zhang, W. 2011. Fork head transcription factor is required for ovarian mature in the brown planthopper, *Nilaparvata lugens*(Stal.) *Molecular Biology* 12: 1471-2199.

*Zhang, Z.Q. and Gu, J.Y. 1985. The nutritive effect of some amino acids in rice plants on the brown planthopper, *Nilaparvata lugens* (Stal.*). Acta-Entomologica Sinica* 28 (1): 15-21.

* Original not seen.

Appendices

Appendix 1: Reaction of 176 rice genotypes against BPH (*Nilaparvata lugenes* Stal.)

S.NO.	DESIGNATION	PARENTAGES	Average plant damage score	REMARK
1	R 1662-1419-2-742-1	R 1004-5552-1-1 x Danteshwari	9.00	S
2	R 1677-1880-8-1381-1	R 1037-649-1-1 x Danteshwari	4.26	MR
3	R 1670-1134-1-115-1	Samleshwari x Poornima	4.89	MR
4	R 1672-4125-488-1	Samleshwari x Dantehswari	9.00	S
5	R 1678-4410-1-493-1	R 1037-649-1-1 x Poornima	4.00	MR
6	R1860-783-2-425-1	R 1099-2596-1-1x RF13	4.87	MR
7	R1860-783-3-426-1	R 1099-2596-1-1x RF13	3.10	MR
8	R1902-917-1-517-1	Denteshwari x JGL 1118	3.50	MR
9	R 1695-2152-1-268-1	Danteshwari x Poornima	3.27	MR
10	R1672-126-1-64-1	R1027-2282-2-1 x Denteshwari	9.00	S
11	R1695-270-2-133-1	Denteshwari x Poornima	9.00	S
12	R1902-912-2-512-1	Denteshwari x JGL 1118	9.00	S
13	IR83376 B - B 110-3	Not available	2.28	R
14	PR26703-3B-PT25	Not available	2.33	R
15	R 1652-2701-2915-1	Madhuri x R 979-1528-2-1-1	2.82	R
16	R 1625-1211-2-765-1	Denteshwari / Tarori Basmati	3.10	MR
17	R 1695-2155-1-270-1	Danteshwari x Poornima	5.11	MS
18	R 1695-2169-1-274-1	Danteshwari x Poornima	4.66	MR
19	R1738-504-3-255-1	IR 64x Pusa Basmati	9.00	S
20	R 1654-2715-2-2936-1	R 1037-1172-1 x Poornima	9.00	S
21	R 1670-3977-1-486-1	Samleshwari x Poornima	9.00	S
22	R 1678-4411-1-494-1	R 1037-649-1-1 x Poornima	9.00	S
23	Danteshwari	(Check)	9.00	S
24	Annada	(Check)	9.00	S
25	Samleshwari	(Check)	9.00	S
26	Vandana	(Check)	9.00	S
27	R1702-542-1-287-1	Poornima x R 979-1528-2-1	5.10	MS
28	R1629-227-1-1868-2	HMTx Jira Shankar	5.27	MS
29	R 1675-1844-2-1257-1	R 1037-649-1-1 x Mahamaya	1.58	R
30	R 1667-1025-1-97-1	R 1060-1674-1-1 x Chandrahasini	1.47	R
31	R 1688-2077-1-262-1	R 975-897-1-1 x Tarori Basmati	1.24	R
32	R 1677-1375-1-157-1	R 1037-649-1-1 x Dantehswari	7.35	S
33	R 1677-1891-3-1435-1	R 1037-649-1-1 x Danteshwari	3.80	MR
34	R 1700-2240-4-2295-1	Danteshwari x Amrit Bhog	2.10	R

35	R 1744-4901-1-510-1	IR 36 x Pau 3056	2.02	R
36	R 1723-1411-1-355-1	Nidhee x IR36	1.75	R
37	R 1723-1413-3-357-1	Nidheex IR36	1.03	R
38	R 1600-1124-3-619-1	MTU 1010 x Triguna	7.11	S
39	R 1707-2291-3-2392-1	MTU 1001 x Poornima	6.92	MS
40	IRH-82	Not available	7.07	S
41	IRH-83	Not available	5.90	MS
42	IRH-84	Not available	4.29	MR
43	RS 2011-101	Not available	9.00	S
44	IR 84887-B-15	MLT 11-24	9.00	S
45	Sasyasree	(Check)	3.41	MR
46	R 1663-1473-2-816-1	R 1004-5552-1-1 x Poornima	9.00	S
47	R 1682-1997-6-1754-1	IR 36 x Triguna	1.92	R
48	R 1702-3677-1-4734-1	Poornima x R 979-1528-2-1	9.00	S
49	R 1657-2899-1-3333-1	Swarna x Indira - A 9	9.00	S
50	R 1557-563-1-83-1	Swarna x Indira A 9	9.00	S
51	UPR 2937-9-3-1	Not available	9.00	S
52	R 1138-688-3-533-1	IR 64 / Pusa basmati-1	9.00	S
53	R 1532-1101-1-119-1	Swarna / IET 14074	9.00	S
54	R 1700-2247-1-2313-1	Danteshwari x Amrit Bhog	9.00	S
55	IRH 43	Not available	3.17	MR
56	R 1238-696-821-3-1	Mahamaya / R 671	9.00	S
57	R 1720-2550-4-2644-1	BG 380-2 x IR 64	2.15	R
58	PSB RC 68	Not available	1.84	R
59	R 1641-391-1-61-1	MTU 1001 x Swarna	9.00	S
60	R1656-428-10-1955-1	Swarna x Jira Shankar	9.00	S
61	R1750-937-1-530-1	BG380-2xAmrit Bhog	9.00	S
62	R 1656-1146-1-510-1	Swarna x Jira Shankar	9.00	S
63	RS 2011-201	Not available	9.00	S
64	Indira Sona (hybrid)	(Check)	9.00	S
65	Jaya	(Check)	3.32	MR
66	Bamleshwari	(Check)	9.00	S
67	Karma Mahsuri	(Check)	9.00	S
68	Mahamaya	(Check)	9.00	S
69	R 1695-2193-6-2171-1	Danteshwari x Poornima	7.40	S
70	R 1677-1375-1-157-1	R 1037-649-1-1 x Dantehswari	7.22	S
71	R 1599-594-2-305-1	MTU 1010 x Mahamaya	4.98	MR
72	R 1661-605-84-1	R 1004-5552-1-1 x Nagri Dubraj	9.00	S

73	R 1688-2150-5-2060-1	R 975-897-1-1 x Tarori Basmati	1.92	R
74	R 1677-1891-3-1435-1	R 1037-649-1-1 x Danteshwari	4.24	MR
75	R 1553-1369-2-252-1	Mahamya / Nidhee	3.00	MR
76	R 1528-106-1-56-1	MTU 1001 / Chatnya	9.00	S
77	R 1551-1066-1-449-1	Madhuri x Mahamaya	9.00	S
78	R 1217-2	Shyamala / IR36 / Shyamala	7.29	S
79	R 1519-781-1-594-1	Rastic Br 240-47 / Charder	3.15	MR
80	R 1519-815-1-646-1	Rastic Br 240-47 / Charder	9.00	S
81	R 1518-725-849-3	IR 64 / Laxmi Bhog	3.21	MR
82	R 1700-2240-4-2295-1	Danteshwari x Amrit Bhog	2.06	R
83	R 1577-642-1-208-1	Triguna / Madhuri-11	6.27	MS
84	R 1625-1203-1-753-1	Denteshwari / Tarori Basmati	9.00	S
85	R 1667-1025-1-97-1	R 1060-1674-1-1 x Chandrahasini	9.00	S
86	R 1688-2077-1-262-1	R 975-897-1-1 x Tarori Basmati	1.04	R
87	R 1670-3975-1-485-1	Samleshwari x Poornima	9.00	S
88	R 1747-4941-1-515-1	Rastic Br 240-47 x Shay- Jira	1.49	R
89	R1700-301-1-155-1	Denteshwari x Amrit Bhog	1.35	R
90	R1700-304-1-161-1	Denteshwari x Amrit Bhog	1.54	R
91	R 1695-2152-2-269-1	Danteshwari x Poornima	7.80	S
92	R 1700-2240-1-2292-1	Danteshwari x Amrit Bhog	9.00	S
93	R 1700-2243-2-2312-1	Danteshwari x Amrit Bhog	1.74	R
94	R 1432-251-103-1-1	IET 14876 / Pusa Basmati-1	3.67	MR
95	Pusa basmati- 1	(Check)	9.00	S
96	IR 64	(Check)	2.25	R
97	Chandrahasini	(Check)	2.48	R
98	R1656-420-9-1945-1	Swarna x Jira Shankar	7.20	S
99	R1656-425-4-1949-1	Swarna x Jira Shankar	9.00	S
100	R 1656-2821-1-3245-1	Swarna x Jira Shankar	9.00	S
101	R 1656-2826-1-3261-1	Swarna x Jira Shankar	9.00	S
102	R 1661-1372-1-601-1	R 1004-5552-1-1 x Nagri Dubraj	3.30	MR
103	R 1607-321-1-34-1	SR 12 x Chinni Kapoor	6.21	MS
104	R 1557-1321-1-591-1	Swarna x Indira - A 13	9.00	S
105	R 1656-3179-2-419-1	Swarna x Jira Shankar	9.00	S
106	R1656-77-1-45-1	Swarna x Jira Shankar	3.76	MR
107	R1629-222-9-1866-1	HMTx Jira Shankar	9.00	S
108	R1629-227-1-1868-2	HMTx Jira Shankar	7.26	S
109	R1629-234-6-1883-1	HMTx Jira Shankar	5.87	MS
110	R1629-234-7-1884-1	HMTx Jira Shankar	2.29	R

111	R1629-234-8-1885-1	HMTx Jira Shankar	7.45	S
112	R1656-420-7-1943-1	Swarna x Jira Shankar	9.00	S
113	R1656-428-10-1955-1	Swarna x Jira Shankar	9.00	S
114	R1656-431-3-1968-1	Swarna x Jira Shankar	9.00	S
115	R1656-431-10-1975-1	Swarna x Jira Shankar	9.00	S
116	R1629-234-1-1878-1	HMTx Jira Shankar	9.00	S
117	R 1656-2823-2-3249-1	Swarna x Jira Shankar	9.00	S
118	R 1656-1146-1-510-1	Swarna x Jira Shankar	9.00	S
119	R 1521-950-6-843-1 (21841)	R 1521-950-6-843-1	9.00	S
120	R 1536-136-1-77-1 (21842)	R 1536-136-1-77-1	6.47	MS
121	R 1698-3644-3-4696-1	Danteshwari x Elaychi	9.00	S
122	R 1656-3173-1-415-1	Swarna x Jira Shankar	9.00	S
123	R 1656-1199-2-551-1	Swarna x Jira Shankar	2.53	R
124	R 1656-2816-9-3223-1	Swarna x Jira Shankar	9.00	S
125	R 1605-315-1-31-1	SR 12 x Jira Shankar	1.46	R
126	R 1458-231-1-275-1	Abhaya / Madhuri	1.33	R
127	Ganjeikalli	Not available	9.00	S
128	R 1536-1170-5-140-1	R302-111 / Ganga Baru	2.21	R
129	R 1630-1237-2-827-1	SR 12 / Laxmi Bhog	9.00	S
130	IET 21053 (NDR9542)	Not available	9.00	S
131	R 1607-673-2-322-1	SR 12 x Chinni Kapoor	5.18	MS
132	R 1656-1146-4-512-1	Swarna x Jira Shankar	9.00	S
133	R 1656-1146-5-513-1	Swarna x Jira Shankar	1.59	R
134	CR 2616-3-3-3-1	Not available	5.19	MS
135	Badsha bhog	(Check)	9.00	S
136	Chinnor	(Check)	9.00	S
137	Mahisugandha	(Check)	9.00	S
138	Indira Sugandhit Dhan 1	(Check)	1.61	R
139	Dubraj (Rajeev)	Not available	1.26	R
140	Shamjeera (Rajeev)	Not available	9.00	S
141	Vishnu bhog (Rajeev)	Not available	9.00	S
142	R 1661-1372-1-601-1	R 1004-5552-1-1 x Nagri Dubraj	9.00	S
143	R1700-302-1-156-1	Denteshwari x Amrit Bhog	2.15	R
144	R1700-308-3-170-1	Denteshwari x Amrit Bhog	2.23	R
145	R1700-309-1-171-1	Denteshwari x Amrit Bhog	1.95	R
146	R1926-1013-2-595-1	R1130-80-1-52-1xHURFG 4-6	9.00	S
147	R1750-937-1-530-1	BG380-2xAmrit Bhog	5.06	MS
148	IR 77537-24-1-1-3	Not available	2.36	R

149	IR 78554-145-1-3-2	Not available	1.13	R
150	YN 3159-15-2	Not available	9.00	S
151	IR 81166-39-1-2-3	Not available	1.61	R
152	R 1625-1204-1-754-1	Denteshwari / Tarori Basmati	9.00	S
153	R 1711-2485-4-2593-1	R 1037-649-1-1 x Nidhee	2.37	R
154	R 1695-2155-1-270-1	Danteshwari x Poornima	9.00	S
155	R 1695-2169-1-274-1	Danteshwari x Poornima	2.05	R
156	R1738-504-3-255-1	IR 64x Pusa Basmati	9.00	S
157	R1757-540-3-286-1	IR 64x Bishanu Bhog	1.81	R
158	R 1799-311-102-1	Danteshwari x WGL 320100	9.00	S
159	R 1779-311-2-103-1	Danteshwari x WGL 320100	4.73	MR
160	R 1779-320-1-111-1	Danteshwari x WGL 320100	9.00	S
161	R 1819-473-1-139-1	Shyamla x MR 219	9.00	S
162	R 1892-489-1-152-1	R 650-1817 x Pusabasmati	9.00	S
163	R 1919-573-1-160-1	Shyamla x G 93-02	9.00	S
164	R 1938-620-1-163-1	Abhaya x B 644-FMR-6-0-0	3.73	MR
165	R1775-565-1-308-1	Denteshwari x CRN 2202-118	9.00	S
166	Chandrahasini	(Check)	9.00	S
167	Dubraj	(Check)	7.20	MS

R **:-** Resistant -39
MR **:-** Moderately resistant - 24
S **:-** Susceptible 92
MS **:-** Moderately susceptible -12