THE EFFECT OF DIFFERENT DOSES OF NITROGEN FERTILIZER (UREA) ON THE INCIDENCE OF SUCKING INSECT PESTS OF RICE

MD. SABUJ ALAM

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2016

THE EFFECT OF DIFFERENT DOSES OF NITROGEN FERTILIZER (UREA) ON THE INCIDENCE OF SUCKING INSECT PEST OF RICE

BY

MD. SABUJ ALAM

REG. NO. : 09-03648

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2016

APPROVED BY:

Prof. Dr. Md. Serajul Islam Bhuiyan
Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. Tahmina Akter
Co-Supervisor
Department of Entomology
SAU, Dhaka

Dr. Mst. Nur Mahal Akter Banu
Chairman
Department of Entomology
and
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'The effect of different doses of nitrogen fertilizer (urea) on the incidence of sucking insect pests of rice'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in Entomology, embodies the result of a piece of *bonafide* research work carried out by **Md. Sabuj Alam**, Registration number: **09-03648** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: June, 2016

Dhaka, Bangladesh

Prof. Dr. Md. Serajul Islam Bhuiyan

Supervisor

&

Department of Entomology

Sher-e-Bangla Agricultural University

Dhaka-1207

DEDICATED

TO

MY Beloved PARENTS

ACKNOWLEDGEMENT

All of my gratefulness to almighty Allah who enabled me to accomplish this thesis paper.

I would like to express my heartiest respect, deepest sense of gratitude, profound appreciation to my supervisor, **Dr. Md. Serajul Islam Bhuiyan**, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.

I would like to express my heartiest respect and profound appreciation to my co-supervisor, **Professor Dr. Tahmina Akter**, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.

I express my sincere respect to the **Dr. Mst. Nur Mohal Akhter Banu,** Chairman, Examination Committee, Department of Entomology and all the teachers of the Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.

I would like to thank all of my family members who have helped me with technical support to prepare this thesis paper. I also thank all of my roommates and friends to help me in my research work.

Mere diction is not enough to express my profound gratitude and deepest appreciation to my mother, brothers, sisters, and friends for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate me to this level.

The Author

THE EFFECT OF DIFFERENT DOSES OF NITROGEN FERTILIZER (UREA) ON THE INCIDENCE OF SUCKING INSECT PESTS OF RICE

BY

MD. SABUJ ALAM

ABSTRACT

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from April to August 2016, to evaluate the effect of different doses of nitrogen fertilizer (urea) on the incidence of sucking insect pest of rice. BRRI dhan43 were used as the test crop in this experiment. The experiment comprised of the following nitrogen doses as treatment- T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application and T_6 = Untreated control. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data was recorded on insect pest incidence, number of healthy, infested plants, leaf and tillers due to different insect pests and infestation level and also yield contributing characters and yield of BRRI dhan43 from different treatments. It was revealed that 3 common species of sucking insect pests such as brown plant hopper, green leaf hopper and rice bug were found in rice field. Insect populations for 5 selected hills/plot were observed and sucking insect pests e.g., brown plant hopper, green leaf hopper and rice bug were investigated. In case of tillers, leaf and panicle infestation in different crop stages caused by different rice sucking insect pests, the lowest infestation was recorded from T_3, whereas the highest infestation was observed from T_5. In consideration of yield contributing characters and yield of BRRI dhan43, the maximum number of filled grains/panicle (93.38%) was recorded from T_3, while the minimum number of filled grains/panicle (73.36%) from T_6. The highest grain yield (4.25 t/ha) was recorded from $T_{3,}$ while the lowest grain yield (1.24 t/ha) was recorded from T_6 followed by T_5 (2.55t/ha). Among the different nitrogen doses; 70 kg N/ha applied in T_3 treatment was superior to other nitrogen doses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FUGURE

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is the most important food crop around the world and the staple food for approximately more than two billion people in the Asia (Hien *et al*., 2006). Ninety percent of all rice is grown and consumed in Asia (Anon., 1997, Luh, 1991). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in shortage of food. The nation adding about 2.3 million every year to its total of 150 million people (Momin and Husain, 2009). Thus, the present population will swell progressively to 223 million by the year 2030 which will require additional 48 million tons of food grains (Julfiquar *et al*., 2008). Population growth demands a continuous increase in rice production. So, the highest priority has been given to produce more rice in Bangladesh (Bhuiyan, 2004). Rice production has to be increased at least 60% to meet up food requirement of the increasing population by the year 2020 (Masum, 2009).

In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. However, in Bangladesh, the average yield of rice is about 2.92 t ha^{-1} (BBS, 2014) which is very low compared to other rice growing countries of the World, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (FAO, 2009). In Bangladesh, rice dominates over all other crops and covers 75% of the total cropped area of which around 79% is occupied by high yielding rice varieties (BBS, 2014). Rice yield can be increased in many ways of them developing new high yielding variety and by adopting proper agronomic management practices to achieve their potential yield. Suitable planting geometry, the most obvious advantage to be the yield increase without any new seeds or chemical and mechanical inputs (Stoop *et al*., 2002) and that is reported to be from 50% to 200% (Uphoff, 2005; Deichert and Yang, 2002; Wang *et al.,* 2002; Wang *et al*., 2006). Rice is more nutritious than any other cereal crops and is an ideal host for over 800 species of insect (Barr and Smith 1975). In tropical Asia, more than 100 species of insects are persistent to rice. Among them, only about 20 species are of major important and regular occurrence (Grist and Lever 1969). In Bangladesh, rice covers almost 84% of the total cultivable land and T. aman alone occupies 46.30% of rice cultivated land.

The rest 26.85, 17.59 and 9.26 % of the lands are occupied by Boro, Aus and Sown Aman, respectively (BBS 2004).

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic zones, to nourish the mankind. Earlier studies reveal that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice. Given the importance of nitrogen fertilization on the yield in grain from the rice plant, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and other agronomic parameters such as the cycle, plant height, lodging and moisture content of the grain, in order to obtain better knowledge of said productive response. Tanaka *et al*. (1966) showed that the height of a rice plant is positively correlated to the length of the maturation cycle. A taller plant is more susceptible to lodging and responds less well to nitrogen. Panicles with a low percentage of sterile flowers permit the application of higher doses of nitrogen and produce better yields. Some factors, like early sowing, meet the twin objectives of producing higher yields and improving the grain quality. Other factors, like increased rates of fertilizer nitrogen, may increase the yield but reduce the quality of the grain. An adequate supply of nitrogen to the crop plants during their early growth period is very important for the initiation of leaves.

The possibility of horizontal expansion of rice production area has come to a standstill and, farmers and agricultural scientists are diverting their attention towards vertical expansion of production. Therefore, attempts should be taken to increase the yield per unit area. For vertical expansion, the use of modern production technologies should be included, use of quality seeds, high yielding and hybrid varieties, optimum age of seedling, optimum number of seedling hill^{-1}, adopting proper plant protection measures, seedling raising techniques, fertilizer management, Insect pests management and so on. Among them optimum use of nitrogen is the major constraints for the successful rice production. Recently various rice varieties were developed and available as BRRI dhan and majority of them is exceptionally high yielding have larger panicles, heavier seeds, resulting in an average yield increase of 7.27% (Bhuiyan *et al.,* 2014). This variety however, needs further evaluation under different adaptive condition to interact with different environmental conditions and investigation of optimum use of nitrogen and their pest infestation level is a major one.

Major sucking pests as brown plant hopper (BPH), Green leaf hopper (GLH) and Rice bug incidence vary on different nitrogen doses. Higher nitrogen doses cause for higher sucking pests incidence. Nitrogen (N) has been an important yield determinant of the flooded rice production systems. High prices, food shortages in developing world and the adverse effects of heavy N losses from flooded fields, however necessitate optimal use of N, nitrogen losses through ammonia volatilization, leaching and run off have been recorded from 20-80% in the rice production (Singh et al., 1998; Griggs *et al*., 2007; Norman *et al*., 2009). Economic use of nitrogen fertilizer is especially important for small growers as urea prices are continuously on rise. The response of rice crop to nitrogen fertilizers have been well documented, however the effects of application rates on yield and quality of rice are lacking. Non-judicious uses of nitrogen fertilizer suppress paddy growth and yield (Rashid, 1996). They observed that higher N contents in plant tissues by urea application were due to better growth, increased N solubility and increased root efficiency for N uptake. Under submerged conditions, urea is more efficient as compared to nitrate containing fertilizers. Urea-N application lowers soil pH and it forms NH_3^- availability under alkaline conditions (Gao *et al.,* 2012).

In Bangladesh, about 175 insect pest species have been reported, which cause damage to the rice plants (Mustafi *et al*., 2007). The estimated loss of rice in Bangladesh due to insect pests and diseases amounts to 1.5 to 2.0 million tons (Siddique, 1992). In Bangladesh two species of plant hopper infest rice. These are the brown plant hopper (BPH) and the white backed plant hopper (WBH). High population of plant hoppers cause leaves to initially turn orange-yellow before becoming brown and drying. This condition, called hopper burn, kills the plant. The feeding damage caused by plant hoppers results in the yellowing of the plants. At high population density, crop loss may be 100% (Rahman *et al*., 2004). For the management of rice insect pests, many options such as chemical, cultural, mechanical, biological etc. are available. Cultural and mechanical control in combination with insecticide reduced insect pest infestation and increased yield with the highest BCR (Alam *et al*., 2003 and Rahman *et al*., 2002). Cultural control is the deliberate manipulation of the environment and cultural practices can be usually employed such as sanitation or destruction of debris, destruction of alternate hosts and volunteer plants, changing dates of planting and harvesting to avoid pest attack, crop rotation to avoid building up of pests, tillage practices, cropping system or intercropping, plant density, trap crops or trap logs, water management, etc. Mechanical control denotes removal of insect pests or infested plant by using mechanical devices i.e. hand picking. Chemical control is generally being advocated for the management of insect pests of rice. Various control strategies have been adopted against rice pests, one common method being the use of synthetic insecticides, which can be environmentally disruptive and can result in the accumulation of residues in the harvested produce and creating health hazards (Chinniah *et al.,*1998). The use of chemicals led to impose certain well known undesirable side effects including environmental pollution, resurgence, upset, resistance to pesticides, and develop high pesticide residues. On the other hand, non-chemical control plays an important role in evolving an ecologically sound and environmentally acceptable method.

Present study has been designed to identify optimum doses of nitrogen fertilizer for lower incidence of sucking insect pests and higher grain yields and better quality of rice with fulfilling the following

Objectives

- To assess the level of incidence caused by sucking insect pests such as brown plant hopper (BPH), rice green leaf hopper (GLH) and rice bug.
- To find out the proper dose of nitrogen against these insect pests.

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characteristics of rice are considerably depended on the manipulation of basic ingredients of agriculture. The basic ingredients include varieties of rice, environment, agronomic practices (planting time &density, fertilizer, irrigation etc.) and insect pest management etc. Among the mentioned factors different doses of nitrogen on the incidence in rice field are more responsible for the growth and yield of rice. Rice suffers heavy losses every year due to attack of many sucking insect pests, among those, Brown plant hopper (BPH), Green leaf hopper (GLH) and rice bug etc. Brown plant hopper (BPH) is the most important. They cause huge damage of grain, leaf, stem and ultimately yield. But research works related to these pests and their incidence on rice related with different nitrogen doses. Optimum doses of nitrogen result in minimum insect incidence are required for better rice production. That's limited in Bangladesh as well as the World. The research work so far done in Bangladesh and elsewhere is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Brown plant hopper (BPH)

The pest, BPH belongs to the plant sucking group of insects called Homoptera. It has been a serious pest of rice in Japan for many years and in Taiwan since 1960.

Until 1970, the insect was only a minor pest in the tropics, but now the BPH has greatly increased in abundance and caused heavy yield losses in many countries. Considering the unpredictable nature of infestations and the severe damage caused, the BPH is regarded as the most serious pest of rice in today's South, South-East Asia and the Fareast (Alam *et al*., 1988).

2.1.1 Systematic position of brown plant hopper

Phylum: Arthropoda

Class: Insecta

Order: Homoptera

Family: Delphacidae

Genus: *Nilaparvata*

Species: *Nitaparvata lugens*

2.1.2 Distribution of brown plant hopper

The BPH is widely distributed in South, South East and East Asia in the South Pacific Islands and Australia. Earlier reports listed specific countries of incidence. But presently, the insect is distributed in Bangladesh, India, Pakistan, Sri Lanka, Nepal, Cambodia, Vietnam, Thailand,China,Taiwan, Malaysia, Singapore, Indonesia, Philippines, Korea, Hong Kong, Japan, Australia and on many Islands of South East Asia, Micronesia and Melanesia like Caroline and Mariana Islands, Fiji, Papua New Guinea and Solomon Islands (Alam *et al*., 1988).

BPH cannot survive the winter in Japan and migrate to Japan each year from the Chinese mainland. Plant hoppers must have the ability to fly continuously for at least 30 and up to 48 hours. The migrations of BPH from the Asian mainland to Japan entail over-water flights of at least 750 km, or if the migrants originate in south-east China, over 1200km (Holt *et al*., 1996).

The mass immigration of plant hoppers occurs every year during late June to middle July because this timing is the rainy season in Japan and plant hoppers can fly to Japan on the lower jet stream that is formed in a seasonal rain front from main land China to Japan.

2.1.3 Nature of damage

Raddy, *et al*., (1993) observed that among the insect pests of rice, BPH is one to the most important. It remains at the base of the plant and sucks the phloem sap from the growing plant. Both the nymph and adult infest the rice crop at all stages of plant growth. They insert their stylet into the plant tissue and suck sap from the phloem cells. Apart from the direct damage, BPH also acts as vector of virus diseases in several rice growing countries. As a result of their feeding, the lower leaves start drying from the tips.

Misra (1980) observed that yellowing starts uniformly up to the mid half from the tip of the leaf and the other half remains yellowish green. Then the whole leaf dries up in addition, the BPH blocks the ascent of nutrition by laying numerous egg masses in the midribs of leaf sheath and leaf blade.

Heinrichs *et al.* (1985) reported that at early infestation stage of feeding by BPH caused round yellow patches in the field, which soon turned brownish due to the drying up of the plants Thus condition is called "Hopper burn' which may spread out and cover the entire field.

Reissig *et al*. (1985) observed that the BPH removes more plant sap than it can digest. The excess plant sap which is high in sugar is expelled from the body as honeydew. The honey dew drops fall on the base of plants and in time turn black from infection by a sooty mold fungus.

Nath and Bhagabati (2005) reported that the leafhopper population was first appeared in the rice seedbed during June- July, reaching the peak in October - November in the main rice field and disappeared from field from December to May. They also reported that the population of *N. virescens*, the most efficient vector of rice tungro virus disease was low compared *to N. nigropictus*, but more than *Recilia dorsalis*.

Tsueda *et al*. (2002) studied on the occurrence of rice bugs, a total of 22 species, in rice fields. They also observed that *Stenotus rubrovittatus* was the important species and the peak occurrence of it coincided with the date of heading of early -ripening rice. They further reported the populations of bugs and rate of damaged rice was related to the area of heading rice.

Mallick and Chowdhury (2000) observed the population dynamics of zigzag leafhopper in rice ecosystems. They found that one peak appearance of this insect was from April to May and the second one from October to November. They also reported that *R. dorsalis* was the less efficient vectors of rice tungro virus than *N. virescens* and *N. nigropictus* to some extent; its presence in seed beds was expected to play a vital role on the carryover of the virus.

Reddy *et al*. (1995) stated that both nymphs and adults infest the rice crop at all stages of plant growth. They insert their stylet into plant tissue and suck sap from the phloem cells. Apart from the direct damage, brown plant hopper (BPH) acts as a vector of virus disease in several rice growing countries.

Chakraborty *et al*. (1990) studied that the abundance of rice pests at 2 sites in Bihar and Orissa, India. Patterns of relative pest abundance were similar in most years of the study. 'Ibey also found that *Nilapurvata lugens* was the most abundant pest at the Orissa site. While *Nephotettix sp*. were the most abundant at the Bihar site. The most abundant natural enemies of rice pests at both sites were *Cyrtorhinus lividipennls* and spiders of the families Lycosidae and Tetragnathidae.

Cook and Perfect (1989) investigated the population dynamics of 3 vectors of rice tungro bacillifrom and spherical viruses, *N. virescens, N. nigropictus and Recilia* d*orsalis* in farmers' fields. They also reported that *R. dorsalis* was the most abundant vector species on the rice seed beds.

Gupta *et al*. (1989) reported that the pentatomids Nezara viridula and Eusarcoirs lewisi is used 6.9%-14.8% grain damage during the dry season and 2.3%- 8.1% grain damage during the wet season.

Reduced settling on the resistant varieties was attributed to chemical cues, mainly the hydrocarbon and carbonyl containing fractions of the surface wax (Woodhead and Padgham, 1988).

Velusamy (1988) reported that significantly more individual of *N. lugens* were settled on susceptible TNI rice plants than resistant ones.

Sharivastava *et al*. (2000) found that the major period of activity of both species was September to November with the highest in October. The frequency of peaks in the catches indicated the possibility of the completion of 4 to 5 generations during the kharif season (July to December)

The green leaf hoppers, *Nephotettix spp*. (Homoptera: Cicadellidae) are most devastating pests of rice throughout the rice growing areas of Asia (Razzaque *et al*. 1985). These have been reported from Bangladesh, Bhutan India, Indonesia, Kampuchca, Malaysia, Nepal, Phillippiiiess, Sri Lanka, Thailand, and Vietnam (Heinrichs et al. 1982; Reissing *et al.* 1985). They don't do only cause direct damage by sucking plant sap and by ovipositing on the leaf sheath but also act as efficient vector of rice tungro virus, one of the most menacing diseases of rice.

As a result of feeding both the nymphs and adults at the base of tillers, plants turn yellow and dry up rapidly. At early infestation, round yellow patches appear which soon turn brownish due to the drying up of the plants. This condition is called hopper burn. The patches of infestation then may spread out and cover the entire field (Heinrichs *et al.*, 1985).

Misra *et al.* (1985) reported that the seasonal changes in population density of *Nephotettix virescens, N. nigropictus, Nilaparvata lugens, Sogatella furcfera* and *Nisia airovenosa,* which are important pests of rice in India during the kharif season.

Zhang *et.al* (1984) reported that population number of *N. lugens* on the new rice lines viz. Hong-Yuan and Tainuo-Xuan were less than the susceptible variety TN1. Alam *et al.* (1983) reported that the brown plant hopper has become a serious pest of high yielding variety of rice. The leaf hoppers feed on the leaves and supper parts of the rice plant whereas the plant hopper confines themselves to the basal parts. In the warm and humid tropics, different species of leaf hoppers and plant hoppers remain active year round and their population fluctuates according to the availability of food plants, natural enemies end environmental conditions.

2.1.4 Control measures

Holt *et al.* (1996) observed that insecticide applications are the main control method against BPH in Japan. Crop breeders have made many attempts to develop resistant varieties. However, resistant-breaker strains of plant hoppers have easily appeared. In Japan, the plant hopper's natural enemies decline to very low densities during the winter. When BPH populations start to grow rapidly, the numbers of predators are insufficient to prevent the increase.

Watanabe *et al.* (2009) observed that more than 60% of the rice fields in Japan are planted following the application of persistent systemic insecticides to seeds in nursery–box applications. This treatment provides effective control of the first immigrants.

Different scientists conducted research on varietal performances of different rice varieties to different insect pest infestation. Koral *et al.* (1998) evaluated rice cultivars for resistance to insect pests. Mo-1 Co-29 and lET- 10750 were resistant to major insect pests (white backed plant hopper, leaf folder and stem borer) of rice. These cultivars yield 17.54-17.94% higher grain yields over presently recommended high yielding varieties like Masuri and Narmada Breeders can utilize these promising cultures as donor for developing high yielding and pest resistant variety of rice.

Emmanuel *et al*. (2003) evaluated 65 rice genotypes for their resistance against the white backed plant hopper (*S. furcifera*). The overall assessment in the present study indicated that resistance in rice to WBPH was shown by the combined influence of non-preference, antibiosis and tolerance.

Misra *et al.* (2001) evaluated 27 cultivars for growth performance and pest and disease resistance. Brown plant hopper, *Nilaparvata lugnes* and green leaf hopper, *Nephotettix virescens* were below moderate levels on all cultivars except Suryu- 52, IRRI- 137, MTU- 1001 and Nagarjuna.

White -backed plant hopper, *Sogatella furcfera* which was previously only a minor pest of rice in the Kuttanad region of Kerala, India reached the status of a major pest during the rabi season of 1997-98. The population packed during .January 1998 (Ambikadevi *at al*. 1998).

Quing *et al*. (2000) reported that white-backed plant hopper (*Sogatetta fwqfera*) is becoming a major pest in the rice- cultivating area around Luzhou, Sichuan, China, with the extension of hybrid rice growing in recent years.

2.2 Green leaf hopper

Different species of leaf and plant hoppers infest rice in the Indian subornment. Of these, the green leafhopper, zigzag leafhopper, the white backed plant hopper and the brown plant hopper are considered economically important (Misra and Israel 1970). The several areas, they frequently occur in large number enough to cause hopper burn.

2.2.1 Systematic position of green leafhopper

Phylum: Arthropoda
Class: Insecta
Order: Homoptera
Family: Cicadellidae
Genus: *Nephotettix*
Species: *Nephotettix virescens*

Nath and Bhagabati (2005) reported that the green leaf hopper population was first appeared in the rice seedbed during June- July, reaching the peak in October - November in the main rice field and disappeared from field from December to May. They also reported that the population of *N. virescens*, the most efficient vector of rice tungro virus disease was low compared to *N. nigropictus*, but more than *Recilia dorsalis*.

2.2.2 Distribution green leaf hopper

Mallick and Chowdhury (2000) observed the population dynamics of green leafhopper in rice ecosystems. They found that one peak appearance of this insect was from April to May and the second one from October to November. They also reported that *R. dorsalis* was the less efficient vectors of rice tungro virus than *N. virescens* and *N. nigropictus* to some extent; its presence in seed beds was expected to play a vital role on the carry-over of the virus.

Reddy *et al*. (1995) stated that both nymphs and adults infest the rice crop at all stages of plant growth. They insert their stylet into plant tissue and suck sap from the phloem cells. Apart from the direct damage, green leaf hopper (GPH) acts as a vector of virus disease in several rice growing countries.

Chakraborty *et al.* (1990) studied that the abundance of rice pests at 2 sites in Bihar and Orissa, India. Patterns of relative pest abundance were similar in most years of the study. They also found that *Nephotettix virescens* was the most abundant pest at the Orissa site. While *Nephotettix sp*. were the most abundant at the Bihar site. The most abundant natural enemies of rice pests at both sites were *Cyrtorhinuslivi dipennis* and spiders of the families Lycosidae and Tetragnathidae.

Cook and Perfect (1989) investigated the population dynamics of 3 vectors of *Ricetungro, bacillifrom* and *spherical* viruses, *N. virescens, N. nigropictus* and *Recilia dorsalis* in farmers' fields. They also reported that *R. dorsalis* was the most abundant vector species on the rice seed beds.

2.2.3 Nature of damage

The green leafhoppers, *Nephotettix spp*. (Homoptera: Cicadellidae) are most devastating pests of rice throughout the rice growing areas of Asia (Razzaque *et al*. 1985). These have been reported from Bangladesh, Bhutan India, Indonesia, Kampuchea, Malaysia, Nepal, Phillippiness, Sri Lanka, Thailand, and Vietnam (Alam 1983; Alam and Catling 1976; Heinrichs *et al*. 1982; Reissing *et al*. 1985). They don't do only cause direct damage by sucking plant sap and by ovipositing on the leaf sheath but also act as efficient vector of rice tungro virus, one of the most menacing diseases of rice.

As a result of feeding both the nymphs and adults at the base of tillers, plants turn yellow and dry up rapidly. At early infestation, round yellow patches appear which soon turn brownish due to the drying up of the plants. This condition is called hopper burn. The patches of infestation then may spread out and cover the entire field (Heinrichs *et al.* 1985).

Misra *et al*. (1985) reported that the seasonal changes in population density of *Nephotettix virescens, N. nigropictus,Sogatellaf urcifera,* and *Nisiaatro venosa*, which are important pests of rice in India, Bangladesh during the kharif season.

Zhang *et al*. (1984) reported that population number of *N. lugens* on the new rice lines viz. Hong-Yuan and Tainuo-Xuan were less than the susceptible variety TN1.

Alam *et al* (1983) reported that the green leaf hopper has become a serious pest of high yielding variety of rice. The leafhoppers feed on the leaves and supper parts of the rice plant whereas the plant hopper confines them to the basal parts. In the warm and humid tropics, different species of green leafhoppers and plant hoppers remain active year round and their population fluctuates according to the availability of food plants, natural enemies end environmental conditions. Orientation and settling response of *N. lugens* on rice varieties is gustatory other than olfactory, as the insect discriminate resistant and susceptible varieties only after contact with the phloem sap (Sogawa 1982 and Nugaliyadde 1994).

Hibino (1979) and Chen & Chu (1981) reported that *N. lugens* is vector of the virus diseases-grassy stunt, ragged stunt, wilted stunt.
Soekhardjan *et al*. (1974) reported that in general there is an increase in the level of green leafhopper infestation with the increase of the age of the rice plants.

Hinckley (1963), Kisimoto (1965) and Hiesh (1972) reported that the plant age of 50 to 70 days after transplanting in the fields was the most suitable for green leafhopper population increase.

Alam (1971) found that at IRRI, *N. virescens* were more abundant during the late dry and wet season. Hiesh (1972) also found that green leafhoppers were generally more abundant on the wet season crops than on the dry season crops.
Too much rain could suppress the insect abundance.

2.2.4 Control measures

Watanabe *et al.* (2009) observed that more than 60% of the rice fields in Japan are planted following the application of persistent systemic insecticides to seeds in nursery–box applications. This treatment provides effective control of the first immigrants.

Emmanuel *et al.* (2003) evaluated 65 rice genotypes for their resistance against the leaf hopper (*S. furcifera*). The overall assessment in the present study indicated that resistance in rice to leaf hopper was shown by the combined influence of non-preference, antibiosis and tolerance.

Misra *et al*. (2001) evaluated 27 cultivars for growth performance and pest and disease resistance. Green leaf hopper, *Nephotettix virescens* were below moderate levels on all cultivars except Suryu- 52, IRRI- 137, MTU- 1001 and Nagarjuna. Green leaf hopper, *Nephotettix virescens* incidence was low to moderate in Pusa-basmati, IRRI-123. Basmati and Nagarjuna, hut was trace to low in all other cultivars. The occurrence of biological control agents and natural enemies in these cultivars was also recorded.

Quing *et al*. (2000) reported that leaf hopper is becoming a major pest in the rice-cultivating area around Luzhou, Sichuan,China, with the extension of hybrid rice growing in recent years.
Gupta *et al*. (1989) reported that the pentatomids *Nezara viridula* and *Eusarcoirs ventralis* caused 6.9%- 14.8% grain damage during the dry season and 2.3%- 8.1% grain damage during the wet season.

Reduced settling on the resistant varieties was attributed to chemical cues, mainly the hydrocarbon and carbonyl containing fractions of the surface wax (Woodhead and Padgham, 1988).

Velusamy (1988) reported that significantly more individual of *N. lugens* were settled on susceptible TN1 rice plants than resistant ones.

Sharivastava et *al.* (2000) found that the major period of activity of both species was September to November with the highest in October. The frequency of peaks in the catches indicated the possibility of the completion of 4 to 5 generations during the kharif season (July to December).

Kim *et al.* (1986) observed the low population growth of *N. malayanus* and *N. virescens o*n resistant rice cultivar.

2.3 Rice bug

Rice bug, *Leptocorisa acuta* (Thunburg) and *Leptocorisa oratoria* (Fabricius) are important pests infesting the rice crop at the flowering stage. These are also known as Gandhi bugs because of the peculiar odour they emit. The insects were earlier identified as *Leptocorisa acuta* from India, but now called as *Leptocorisa oratoria* (Fabricius). These two closely related species may occur together in rice fields. They are most abundant at 27 ^{0}C to 28^{0}C and about 80 % relative humidity. Population usually increases at the end of a rainy season but declines rapidly during dry month.

2.3.1 Systematic position of rice bug

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Alydidae
Genus: *Leptocorisa*
Species: *Leptocorisa acuta*

Singh and Chandra (1967) observed that rice bug migrates from alternate hosts to rice fields during the flowering stage. The hibernating adults become active with the onset of summer rains. Intermittent rains and high temperature during summer are conducive to terminating its aestivation. They also found that the rice bug reacts favorably to the higher humidity and rainfall prevailing from April to June in Bihar, India, which are the active season of the bugs.

Tsueda *et al.* (2002) studied on the occurrence of rice bugs, a total of 22 species, in rice fields. They also observed that *Stenotusrubro vittatus* was the important species and the peak occurrence of it coincided with the date of heading of early -ripening rice. They further reported the populations of bugs and rate of damaged rice was related to the area of heading rice.

2.3.2 Distribution of rice bug

Rice bug (*Leptocorisa acuta*) is widely distributed in India, Bangladesh, Bhutan, China, Fiji, Indonesia (Sumatra), Malaysia, New Caledonia and Samoa. *L. oratoria* is distributed in Australia (Queensland), Bangladesh, Bhutan, China, India (Malabar), Indonesia (Sumatra), Malaysia, Solomon island, Sri Lanka and Tibet.

A new distribution map was provided for *L. oratorius* (Fabricius) (Heteroptera: Alydidae) which attacks rice. The information was given on the geographical distribution in Asia, Andaman Islands, Bangladesh, Bhutan, Brunte, China; Xizangy (Tibet). In India the insect was reported from Assam, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal. It is also reported from other countries like Java, Indonesia, Sulowesi, Sumatra, Laos, Malaysia, Sabh, Sarwak, Peninsular Malaysia, Nepal, Philippines, Sri Lanka,Thailand,Vietnam, and Pacific Islands, Australia, Queensland, Papua New Guinea, and Solomon Islands (Anon., 1996).

Historically, *L. oratorius* was first identified as *L. acuta*, and confusingly , the commonly cited *L. varicornis* was actually *L. acuta* (Sands 1977). In Japan there is only one species of RB, but it was first referred to as *L. acuta* then was later changed to *L. chinensis*. Genus *Leptocorisa* was first recorded from India by Atkinson (1889) who recorded the occurrence of *Leptocorisa acuta* (Thunberg). *Leptocorisa acuta* was first described by Thunberg in 1783 under the genus *Cimex*. Results revealed that the commonality among the three main RB species differs by geography and rice culture. *L. oratorius* is most prevalent in the tropics while *L. chinensis* is more common in the temperate regions of North Asia. The distribution of the two main species outside of Japan overlaps in many rice-growing countries. *L. acuta* is more prominent than *L. oratorios* in dry land rice in mountainous regions of tropical Asia. In the wetland areas of NE Thailand, 83 % of RBs collected by sweep net were *L. oratorius* with the balance belonging to *L. acuta* (Suwat Ruay-aree 1997).

Rothschild (1970) reported that the adults of *L. oratorius* feed on grasses like *Echinochloa crusgalli, Paspalum serobiculst,* and *Pennisetum sp* before migrating to paddy fields. During off-season, small number of adults and nymphs were found on ration rice plants and various grasses.

Butani and Jotwani (1976) observed that *L. acuta* hibernate in adult stage on grasses, weeds or in cracks and crevices in the soil. Sands (1977) reported that *Echinocloa colona* L. Link helped in the multiplication of L. *oratorius* and he also stated that the abundance of the pest in bush land and grasses surrounding the paddy crop influenced on the extent of damage on paddy.

Singh and Sinha (1978) carried out fortnightly observation in Bihar from July to December in 1976 and reported that activity period of *L. acuta* was from second to third week of October and the average number per 100 sweeps varied from 10 to 500.

Chhabra and Jaswant Singh (1979) conducted survey on the rice pests during kharif season.The crop was surveyed at thetille ring stage, panicle emergence and pre harvest stage. *L. acuta* was found during the pre-harvest stage.

Garg and Sethi (1980) reported that weekly averages of 28^{o} to 59^{0} C, 69.55 per cent relative humidity, 8 to 18 hours of sunshine and 0 to 71.7 mm rain were found to favor the highest population buildup of *L. acuta* in rice, during kharif season.

Taylo *et al.* (1987) reported that rice bug *L. oratorius* comprises 80 per cent of the Leptocorisa bug from the collections in wet land and dry land rice in Philippines. Similarly *L. acuta* and *L. palawanensis* also found in significant number. Plants in the milk or dough stage are nutritionally acceptable to *L. oratorius* and *E. colona* as the principle alternate weed host. Rai *et al.,* (1990) reported that peak pest population of *L. acuta* was found from 37^{th} to 40^{th} standard weeks when the crop was at milky grain stage.

Suwat Ruayaree (1994) studied the seasonal occurrence of *Leptocorisa spp* and found that bug population was more abundant in milky stage of crop. Sugimoto and Nugaliyadde (1995) reported that *L. oratorius* damage occurs mainly from the very early stage of grain development to the milk ripe stage when the bug infestation was severe. Considerable proportion of damage was seen at the dough and hard-dough stages when the degree of infestation was lower. Chander (1996) studied the intrinsic rate of natural increase of *L. varicornis* on alternate host food plant, E. colona during kharif season. The maximum intrinsic rate of natural increase was estimated during the period from the last week of August to the 3rd week of September.

In Bangladesh the irrigated boro (winter) crop, 60% was comprised of *L. oratorius* (Islam *et al*. 2003). While in temperate Bhutan, Arida *et al*. (1988) found that 70% were *L. acuta*. An illustrated key to both *L. acuta* and *L. Oratorius* has been developed (Barrion & Litsinger 1981). *L. oratorius* adults have spots on the ventro-lateral segments of the abdomen, whereas *L. acuta* does not. *L. oratorius* is longer, 18.5-19 mm, versus *L. acuta* at 13-16.3 mm. Cobblah & den Hollander (1992) were able to separate the two species based on egg morphology alone. *L. acuta* eggs are light brown and shiny while those of *L. oratorius* are dark brown to black and dull. But Torres *et al*. (2010) showed significant morphological variability within and among different geographical populations of *L. oratorius* from three Philippine provinces, therefore, it is expected that *Leptocorisa* species will morphologically vary significantly over their wide ranges. The most widely distributed species is *L. acuta* that occurs in locations where *L. oratorius* has never been recorded.

Ito (2003) reported that the bugs, Nezara viridula, Trigonotylus coelestialium and Eysarcoris lewisi were dominant among 40 species of Hemiptera that cause pecky rice in Japan. He also reported that these bugs fed on the ears of various kinds of grasses, and rice was a preferred food plant. He suggested that weed control around rice fields could reduce bug populations.

High rice bug populations are brought about by factors such as nearby woodlands, extensive weedy areas near rice fields, wild grasses near canals, and staggered rice planting. The insect also becomes active when the monsoonal rains begin. Warm weather, overcast skies, and frequent drizzles favor its population buildup.

The populations of the rice bug increases at the end of the rainy season. Rice bugs are found in all rice environments. They are more common in rain fed and upland rice and prefer the flowering to milky stages of the rice crop.

Adults are active during the late afternoon and early morning. Under bright sunlight, they hide in grassy areas. They are less active during the dry season. In cooler areas, the adults undergo a prolonged development in grasses. They feed on wild hosts for one to two generations before migrating into the rice fields at the flowering stages. The nymphs are found on the rice plant where they blend with the foliage. There, they are often left unnoticed. When disturbed, the nymphs drop to the lower part of the plants and the adults fly within a short distance.

According to Akbar (1958) *L. varicornis* breed on grasses in June-July and migrated to paddy in July-August. Maximum damage was done during September-October and bugs remained inactive during November-December. Paddy sown in June and harvested in September was the main target of attack, while late maturing varieties escaped the damage (Sen and Chaudhuri, 1959). Banerjee (1961) reported that maximum activity of the paddy bug in relation to weather conditions was seen from August to November on Aman paddy in Bangladesh.

Singh and Chandra (1967) observed that rice bug migrates from alternate hosts to rice fields during the flowering stage. The hibernating adults become active with the onset of summer rains. Intermittent rains and high temperature during summer are conducive to terminating its aestivation. They also found that the rice bug reacts favorably to the higher humidity and rainfall prevailing from April to June in Bihar, India, which are the active season of the bugs.

Tsueda *et al.* (2002) studied on the occurrence of rice bugs, a total of 22 species, in rice fields. They also observed that *Stenotus rubrovittatus* was the important species and the peak occurrence of it coincided with the date of heading of early -ripening rice. They further reported the populations of bugs and rate of damaged rice was related to the area of heading rice.

2.3.3 Nature of damage

Rice bugs feed by inserting their needlelike mouthparts into new leaves, tender stems and developing grains. Consequently, the plant reacts to repair the tissue and seal the wound. When injuries accumulate, the plant becomes stressed, which can lead to growth retardation of the grains and some grain and plant deformation. Excessive feeding can cause yellow spots on the leaves. This reduces photosynthesis and, in extreme cases, can damage the vascular system of the plant. Puncture holes also serve as points of entry for several plant pathogens, such as the fungus that causes sheath rot disease. The most economically important damage is caused when the adults and nymphs feed on the developing grains. Such damage causes discoloration of the grains, which reduces market quality. The general nature and symptoms of damage in brief as reported by a number of workers are as follows.

Uichanco (1921) reported that insect feeding by inserting a part of its stylet in to the interior of the rice grain in the milky stage through a weak spot at the place where the edges of the large glumes meet to form the hull. The feeding caused diffused yellowish brown spot leads to empty hull and the bugs might secret harmful enzyme in to the plant cell in addition to the mechanical injury.

According to Rai (1981) both nymphs and adults of rice ear head bugs sucked the milky juice from developing grains, there by prevented grain formation and such grains later shriveled. The ear heads in badly infested fields showed numerous empty grains, which turned brown and dried. Lee et *al*. (1986) reported that *L. oratorius* was the most dominant species associated with grain discoloration in association with fungal pathogen *Fusarium solani* causing “Dirty panicle” disease of rice.

Sugimoto and Nugaliyadde (1995) reported that the grains damaged by *L. oratorius* leads to unfilled grains and showed a dark spot on the grain surface. Damage mainly occurred from the very early stage of grain development. However, a considerable proportion of grains were damaged at the dough and hard dough stages. Litsinger *et al*. (1998) reported that the bugs of *L. oratorius* produced proteinaceous stylet sheaths in all nymphal stages and both adult sexes. Feeding cause’s unfilled grains and about 95 per cent of the sheaths were found at the juncture of lemma and palea. All rice bugs produced sheaths on milk, soft and hard dough grains but adults produced significantly fewer on hard dough rice. Bugs feed mostly in the early morning and least at night.

Berg and Soehardi (2000) reported that *L. oratorius*, which feeds on the panicle of rice, caused the empty seed. Anand Prakash *et al*. (2002) reported that feeding of *L. acuta* caused rice grain discoluration and it was more severe when associated with fungus *Fusarium moniliforme*. Kikuchi et *al*. (2004) reported that the rice ear head bug damage results in picky rice formation. Feeding marks were mainly found on the grain surface along the hooking portion and the basal part of the grain. Jahn et *al*. (2004) studied the effect of *L. oratorius* on grain quality. Feeding caused the unfilled and partially filled grains and also grain discoloration.

Adult females oviposit from the booting stage (the latter part of the panicle development stage) to the milky stage (the early ripening stage when the Endosperm is liquid) of rice development up to 30 eggs are laid in single or double rows, predominantly on the flag leaf and occasionally on the panicle of rice (van der Goot 1949; Rothschild 1970a).Nymphs feed in clusters on soft spikelet. Because the egg-to-egg period lasts 35±70days in tropical regions (Corbett 1930; vander Goot 1949; Rothschild 1970a; Sands 1977; Domingo, Heinrichs & Medrano1982),only on well-time degeneration can Develop per rice crop except when alternative food.

Plants are present early in the season. *Leptocorisa Oratorius* has been reported to reproduce on a number of wild grasses in south-east Asia, although as food plants wild grasses were inferior to rice (Uichanco 1921; Corbett 1930; van der Goot 1949;

Morrill, Pen-Elec & Almazon1990). Adults and nymphs pierce developing rice spikelet and feed on the ovary, liquid endosperm (in the case of milk spikelets) or solid endosperm (in the case of dough spikelet).The point of insertion may Be visible by white exudates that turns into a brown spot. A number of common fungi, however, also cause seed discolorations (van der Goot 1949; Lee *et al* 1986) which are often mistaken for *L. oratorius* attack by farmers and agriculture extension workers. Upon feeding, the bug secretes a stylet-sheath head On the surface of the spikelet, which can be made Visible by staining (Litsinger *et al.* 1981).Sugimoto &

Nugaliyadde(1995). However, found that the stylet-sheath head was often absent from attacked spikelet.

Morrill (1997) observed that, when given the choice on plants in the laboratory, adults strongly preferred (pre) flowering spikelet to milky or dough spikelet. Attack of (pre) flowering spikelet causes empty or partially filled seed (van der Goot 1949; Rothschild 1970b; Morrill1997), or causes dislodge-meant of spikelet (W.L. Morrill, personal communication). Attack of milky spikelet reduces seed Weight. (Morrill 1997) and feeding on dough-stage spikelet may cause stained seed however, farmers are concerned about grain yield, seed ripeness and the proportion of empty seed, not about stained seed. The influence of feeding by *L. oratorius* on rice Yield has been examined in several studies.

Van der Goot (1949) observed in the field that individual Panicles attacked by adults or clusters of nymphs Produced normal seed, and suggested that damage occurred only at high densities of adults. In the laboratory, *L. oratorius* adults were found to probe 1±9 flowering or milky spikelet per day (Rothschild 1970b; Morril l1997; Litsinger Gyawali & Wilde 1998). Based on observations of probed spikelet in the field, Rothschild (1970b) estimated that a field population of 25 adult's m^{-2} would cause 25% grain yield loss in a traditional rice variety. The feeding rates recorded by Litsinger, Gyawali & Wilde (1998), however, indicated that damage would be three times lower. Moreover, Morrill (1997) postulated that it is likely that rice plants will compensate for damage to immature spikelet by filling other spikelet, for not all spikelet develop into filled seed. Extrapolating from observations on individual spikelet to the crop level may therefore be in valid.

2.3.4 Control measures

Remove weeds from fields and surrounding areas to prevent the multiplication of rice bugs during fallow periods. Level fields with even applications of fertilizer and water encourage rice to grow and develop is at the same rate**.** As a preventive measure, the removal of alternate hosts, especially graminaceous weeds, can prevent rice bug populations from reaching damaging levels. This is because the bug requires a wild host to feed and reproduce upon before moving into the rice field in early spring. The use of late-maturing cultivars can reduce feeding damage from the rice bug, as their activity corresponds with warm weather and the flowering stage of host grasses. Irrigation should be managed to avoid excess humidity. Corbett (1930) indicated that nymphs and adults may be attracted to trap crops of grasses or early-planted rice and the insects can be collected before the flowering of the main crop. Flooding is effective in killing rice bug eggs, as well as driving adults to the tops of the rice plants where they are more easily targeted with pesticides.

Planting fields, within a village, at the same time (synchronous planting) also helps reduce rice bug problems. Capturing rice bugs, in the early morning or late afternoon, by net can be effective at low rice bug densities, though labor intensive.

Encourage biological control agents: Some wasps, grasshoppers and spiders attack rice bugs or rice bug eggs. In discriminate insecticide use disrupts biological control, resulting in pest resurgence. Begin scouting the field at pre-flowering and continue daily until the hard dough stage. Count Rice bugs in the early morning or late afternoon from 20 hills while walking diagonally across a transplanted field. Adults often fly out of the way before you reach the rice plant, so counts may only reveal immature forms. Direct control may be required if there are more than 10 rice bugs/20 hills.

The choice of insecticide depends on many factors such as the application equipment available, cost of the insecticide, experience of the applicator, or presence of fish. The benefits of using an insecticide must be weighed against the risks to health and the environment.

A number of workers have tried various insecticides against rice bugs in different countries. However, the review is restricted to only old chemicals that were tried during the study. A number of reports bring out the effectiveness of BHC against rice bugs. The rice bugs were effectively controlled by dusting BHC and DDT 5 per cent dusts at 10 to 25 pounds per acre (Biswas, 1953; Sen and Chaudhuri, 1959; Banerjee, 1961). The findings of Fernando *et al*. (1957) are interesting to note that 0.65 per cent BHC dust was recommended for the control of *L. varicornis*. Srivastava and Saxena (1960) reported that dusting with BHC (5 per cent) was more economical than many other modern insecticides tested. *L. acuta was* satisfactorily controlled by the sprays with carbaryl at 0.75 pounds/acre at Sarawak (Anon, 1964); whereas, Gusathion 0.04 per cent, endosulfan0.06 per cent and gamma BHC 0.022 per cent were found effective against rice bugs at International Rice Research Institute, Manila Anon, 1965).

Teotia and Misra (1965) reported that BHC and aldrin dusts were more effective than spraying DDT (0.3 %) and dieldrin (0.15 %). They also opined that dusting with BHC was more economical. Alam (1965) reported that carbaryl at 0.05 concentration was as effective as other chemicals tried. Comparative assessment on the effectiveness of BHC (25 kg/ha), fenitrothion (1125 ml/ha) and three other chemicals made by Krishnamurthy *et al*. (1977) revealed that fenitrothion recorded maximum reduction of bugs with higher yields per acre followed by BHC dust. Pruthi (1969) reported that dusting the crop with BHC 5 per cent dust at 13 to 17 kg per hectare or spraying with 0.2 percent BHC or DDT suspension at 1120 litres per hectare was effective against rice bug.

Soon (1971) reported that BHC and carbaryl at 0.1per cent concentration controlled the pest effectively. During 1971 again he reported that BHC 0.05 per cent and carbaryl 0.1 per cent spray were most effective against *L. oratorius* at Malaysia. Custodio (1969) reported that 2 to 3 foliar sprays of carbaryl and endosulfan when tested with two other chemicals controlled *L. acuta* effectively. Israel *et al*. (1969) and Chatterjee *et al*. (1977) stated that BHC dusting at 10 to 20 kg per hectare controlled the bugs. Pathak et al. (1978) obtained a good control of bugs with BHC and carbaryl 5 per cent dusts 20 to 25 kg/ha and carbaryl 50 per cent WP 1 g/l of water. Rai and Vidyachandra (1980) recorded 50.55 per cent reduction in population of *L. acuta* in plots treated with sevidol at 0.1 per cent when compared to 93.26 and 88.13 per cent in malathion and fenthion treated plots, respectively.

Rai and Vidyachandra (1980) recorded 50.55 per centreduction in population *of L. acuta* in plots treated with sevidol at 0.1 per cent when compared to 93.26 and 88.13 per cent im malathion and fenthion treated plots, respectively. Spraying IR-36 variety at flowering with endosulfan at 0.06 per cent and carbaryl at 0.12 per cent resulted in 100 and 91 per cent mortality of bugs, respectively (Heinrichs *et al*., 1982).

Krishnakumar and Visalakshi (1989) studied the laboratory bioassay of 12 insecticides on *L. acuta*. Among them malathion, formothion, fenthion and methyl - parathion ranked superior in relative toxicity viz., 7.26, 7.12, 7.06 and 5.74 times toxic to the bug, respectively over the rest of the chemicals. Against *L. acuta*, a number of botanicals viz., 5 per cent aqueous leaf extract of king of bitters (*A. paniculata*), 3 per cent oil emulsion spray of neem (*A. indica*), seed extract of orange (*C. reticulate*) and leaf extract of lemon grass (*C. citrates*) are found to protect developing rice grains and reduce the population of *L. acuta* (Gupta *et al.,* 1990).

Jena *et al.* (1990) opined that chemicals viz., ethofenoprox, monocrotophos and oxydemeton methyl each at 0.5 kg a.i/ha controlled the *Leptocorisa acuta* and were effective for the entire milky grain period of the crop for 9, 11 and 15 days, respectively. Other chemicals like fenabucarb, methyl parathion, malathion, quinalphos and chlorpyriphos gave good knock down control but were not persistent.

Mayabini et *al.* (1990) evaluated 12 insecticides on CV. Java at 0.04 per cent concentration both in green house and field condition for their effectiveness against rice gundhi bug *L. oratorius*. Ethofenoprox, monocrotophos and oxydemton methyl controlled the population effectively during the entire milky stage of panicles whereas BPMC, methyl parathion, malathion, chlorpyriphos and quinalphos though did not persist for a longer period, were capable of knocking down the pest immediately.

Pangtey (1990) reported the efficacy of seven insecticides against *L. acuta*. Of the severe chemicals tested, malathion dust applied at 1 kg a.i/ha was the most effective insecticide (43.75 q/ha), as compared to methyl parathion dust applied at 1 kg a.i/ha (43.25 qt/ha) and dichlorvos Ec @ 0.08% (40.91 q/ha) followed by carbaryl dust 1 kg a.i/ha (39.80 q/ha).

Durairaj and Venugopal (1993) studied the different neem products and their effectiveness against *L. acuta*, compared with that of malathion. The plot treated with 0.05 per cent malathion showed a reduction in the pest incidence of 86.2 per cent, followed by (0.5 %) neemark (2.0%) neem oil and (5.0%) Vitex negundoleaf extract showed a reduction in the pest incidence of 82.8, 69.0, and 50.7 per cent, respectively. Prakash and Rao (1994) reported that (0.5%) and (1.0%) Achook spray effectively controlled the pest of *Leptocorisa acuta*.

Krishnakumar and Visalakshi (1996) conducted a field experiment to assess the efficacy of different insecticides for *controlling L. acuta* at different population levels. In the first experiment, where there was more of a population stress, insecticides such as malathion (0.10 %), methyl parathion (0.05%) and fenthion (0.10 %) were found to be more effective in controlling the bug with the percentage reduction being 75.72 to 97.15, 72.71 to 94.76 and 69.92 to 91.85 per cent, respectively. In the second experiment with lesser population stress also the same insecticides showed the maximum effect in controlling the population in the field.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to evaluate the effect of different doses of nitrogen fertilizer (urea) on the incidence of sucking insect pest of rice. Materials and method Includes location of experiment, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that followed in this experiment has been presented under the following headings.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from April to August 2016.

3.1.2 Site description

The present piece of research work was conducted in the experimental area of Sher-e-bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The location of the site is $23^{0}74$/N latitude and $90^{0}035$/E longitude with an elevation of 8.2 meter from sea level.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest period of the year. Details of meteorological data in respect of temperature (^{0}C), rainfall (cm), relative humidity (%) and sunshine hour during the period of the experiment has been presented in Appendix II.

3.1.4 Soil characteristics of the experimental plot

The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

BRRI dhan43 were used as the test crop in this experiment.

3.2.2 Treatment of the experiment

The experiment comprised of the following nitrogen dose as treatment

T_1= Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application.

T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application.

T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application.

T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application.

T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application.

T_6 = Untreated control.

3.2.3 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogeneous effects. Each block was divided into 6 unit plots as treatments demarked with raised bunds. Thus the total numbers of plots were 18. The unit plot size was 3.0 m × 3.0 m. The distance maintained between two blocks and two plots were 0.5 m and 0.5 m, respectively.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur just 20 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 2ndweek of April 2016 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

Plate 1. The experimental field of the present study at SAU, Dhaka

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of USG, TSP, MP, Gypsum, zinc sulphate and borax, respectively were applied @ 80 kg, 60 kg, 90 kg, 12 kg, 2.0 kg and 10 kg (BRRI, 2013). Urea was applied as urea super granule (USG).The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of land. USG was applied in two equal installments at tillering and panicle initiation stages.

3.3.5 Transplanting of seedling

Twenty five days old seedlings were carefully uprooted from the seedling nursery and transplanted on 24 April, 2016 in well puddled plot. Three seedlings hill^{-1} were used following spacing as per treatment. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.6.1 Irrigation and drainage

Irrigation was provided to maintain a constant level of standing water up to 6 cm in the early stages to establishment of the seedlings and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 30 DAT and 60 DAT by mechanical means.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 12august, 2016 when 80-90% of the grains were turned into straw colored. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded plot wise from 1 m^{-2} areas. The grains were dried, cleaned and weighed for individual plot and adjusted to a moisture content of 14%. Yields of rice grain and straw 1 m^{-2} were recorded from each plot and converted to t ha^{-1}.

3.5 Data collection and calculation

The infestation was expressed as percent 'hopper burn' and 'tungro' calculated by using the formula as suggested by Shafiq *et al*. (2000).

3.5.1 Infestation level

Five hills were selected at random per replicate for each treatment. The tiller infestation and leaves infestation were counted. In case of tiller infestation, it was counted in tillering, panicle initiation, before ripening and after ripening stage and converted into per plant. On the other hand, leaves infestation infested tillers was counted at seedling, tillering, and panicle initiation stage. The observation was recorded at the first observation of symptom and was continued up to maturity of the grains at 7 days interval.

3.5.1.1 Percent of tiller infestation

Number of tiller infestation was counted at tillering, panicle initiation, before ripening and after ripening stage from total tillers per five hills and converted into per plant and percent of tiller was calculated by using the following formula:

$$\% \text{ tiller infestation} = \frac{\text{No. of infested tillers}}{\text{Total no. of tillers per five hills}} \times 100$$

3.5.1.2 Percent of leaf infestation

Number of leaf infestation was counted at seedling, tillering, and panicle initiation stage from total tillers per five hills and percent of leaf infestation was calculated by using the following formula:

$$\% \text{ leaf infestation} = \frac{\text{No. of infested leaves}}{\text{Total no. of leaves per five hills}} \times 100$$

3.5.2 Yield contributing characters and yield of rice

3.5.2.1 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average length was recorded as per panicle in cm.

3.5.2.2 Filled grains panicle^{-1}

The total number of filled grains were collected randomly from selected 10 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1}was recorded.

3.5.2.3 Unfilled grains panicle^{-1}

The total number of unfilled grains were collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1}was recorded.

3.5.2.4 Weight of 1000-grains

The total of 1000 grains was counted and weighed and expressed in gram.

3.5.2.5 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area in each plot were taken as the final grain yield plot^{-1}and finally converted to ton hectare^{-1}(t ha^{-1}).

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments. The mean values of all the characters were calculated and analysis of variance was performed by using MSTAT-C software. The significance of the difference among the treatments means was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of different doses of nitrogen fertilizer (urea) on the incidence of sucking insect pest of rice on rice variety BRRI dhan43. Data was recorded on the incidence of insect pest, number of healthy, infested plants & leaf blade due to different sucking insect pests and infestation level and also yield contributing characters and yield of BRRI dhan43. The analysis of variance (ANOVA) of the recorded parameters has been presented in Appendix IV-XI. The results have been discussed and presented under the following headings:

4.1. Species of sucking insect pests found in the experimental rice field during study period

Rice plants compete with numerous sucking insect pests under favorable condition which is the common phenomenon of rice cultivation. Under the present experiment three common species of sucking insect pests were found and they belong to 3 family under 2 orders. The common name, scientific name, order, family, stages of insects as rice pests and nature of damage are presented in Table 1. Among the recorded insect pests 1 species belong to the family Delphacidae, 1 species belong to the family Cicadellidae and one species belongs to the family Coreidae. All of the insect pests were destructive both in adult and nymphal stages. The nature of the damage of these insects are also presented in Table 1.

4.2 Insect population

Insect population for 5 selected hills/plot were observed with clean observation and in the experimental plot brown plant hopper, green leaf hopper and rice bug was counted and recorded. For different treatment number of different sucking insect pests varied significantly under the present trial. In Bangladesh, about 175 insect pest species have been reported, which cause damage to the rice plants (Mustafi *et al*., 2007)

Table 1. List of the sucking insect pests found in the experimental rice field during study period

Sl. No.	Common name	Scientific name	Order	Family	Stage(g) of insects	Nature of damage
1.	Brown plant hopper	*Nilaparvata lugens*	Homoptera	Delphacidae	Adult and nymph	Suck cell sap from the base level of tiller
2.	Green leaf hopper	*Nephotettix virescens*	Homoptera	Cicadellidae	Adult and nymph	Suck cell sap from the leaf blade and leaves sheath
3.	Rice bug	*Leptocorisa acuta*	Hemiptera	Coreidae	Adult and nymph	Suck cell sap from the developing rice grain

4.2.1 Incidence of rice brown plant hopper

Significant variations among different treatments (containing different nitrogen doses) were observed in respect to the incidence of rice brown plant hopper and it's infestation in the field, which are interpreted and discussed on the following sub-headings:

4.2.1.1 Incidence of rice brown plant hopper at different growing stage of rice

Table 2: Effect of different doses of nitrogen on the incidence of brown plant hopper at the vegetative stage of rice plant at different DAT

Treatment	Incidence of BPH by number at different DAT				
	28 DAT(No. of BPH/2sweeps)	33 DAT(No. of BPH/2sweeps)	38 DAT(No. of BPH/2sweeps)	43 DAT(No. of BPH/2sweeps)	48 DAT(No. of BPH/2sweeps)
T_1	7.17 c	6.97 c	7.65 c	8.15 cd	8.70 bc
T_2	5.70 d	5.53 d	6.92 c	7.07 d	7.54 c
T_3	3.64 e	4.57 d	5.09 d	5.48 e	5.81 d
T_4	8.08 b	8.48 b	9.14 b	9.72 b	10.08 b
T_5	9.34 a	11.07 a	12.90 a	13.26 a	14.12 a
T_6	8.46 b	8.83 b	9.443 b	9.03 bc	9.270 b
$LSD_{(0.05)}$	0.83	1.14	1.28	1.23	1.48
CV (%)	6.45	8.27	8.23	7.66	8.77

In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

The incidence of adult brown plant hopper at the vegetative stage collected from different plots by sweep net was varied significantly and more or less similar trends of results in respect of the incidence of adult brown plant hopper were also observed throughout the growing period (28, 33, 38, 43 and 48 DAT). The incidence of adult brown plant hopper was ranged from 3.64 to 9.34BPH /Plot at 28 DAT, 4.57 to 11.07

BPH /Plot at 33 DAT, 5.09 to 12.90 BPH /Plot at 38DAT and 5.48 to 13.26 BPH Plot at 43 DAT and 5.81 to 14.12 BPH /Plot at 48 DAT (Table 2).All these cases, the highest incidence or number of BPH /Plot was observed in T_5 treatment and the lowest incidence was recorded inT_3 treated plot followed by T_2 treated plot.

Kawada (1954, 54a) described that *N. apicalis*, and *Nilaparvata lugens* Stal. Multiply rapidly, when micro climate is suitable for thick growth of unruffled of the plant.. During July-August if sunshine is less and temperature and humidity high, fast multiplication of the pest can be predicted. At vegetative stage the variations of the different nitrogen doses as treatments where the lowest incidence in T_3 and highest incidence in T_5.Compared with untreated control the incidence of brown plant hopper was higher in T_5 treatment than T_6 treatment. The highest or excess nitrogen application result as higher insect incidence and lowest nitrogen application also result as higher insect incidence but incidence lowest than excess nitrogen application. Optimum nitrogen application result as minimum insect incidence according to Economic threshold level (ETL). However, excess nitrogen application makes the crop succulent and enhanced lodging during grain filling stage result as sucking insect pest incidence increased (Sidhue *et al.*, 2004).

Table 3: Effect of different doses of nitrogen on the incidence of brown plant hopper at the reproductive stage of rice plant at different DAT

Treatment	Incidence of BPH by number at different DAT			
	52 DAT (No. of BPH/2sweeps)	60 DAT (No. of BPH/2sweeps)	68 DAT (No. of BPH/2sweeps)	74 DAT (No. of BPH/2sweeps)
T_1	3.99 b	4.16c	4.30 c	4.47 b
T_2	3.78 b	3.96 c	4.05 c	4.25 b
T_3	2.98 c	2.76 d	2.83 d	2.92 c
T_4	5.84 a	6.29 ab	6.92 ab	6.96 a
T_5	6.20 a	7.10 a	7.39 a	7.46 a
T_6	5.79 a	6.04 b	6.67 b	6.77 a
LSD $_{(0.05)}$	0.66	0.93	0.60	0.72
CV (%)	7.55	10.13	6.14	7.24

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

From table 3, it was revealed that, at the reproductive stage the incidence of adult Brown plant hopper collected from different plots by sweep net was varied significantly and more or less similar trends of results in respect of the incidence of brown plant hopper were also observed throughout the growing period (52, 60, 68 and 74 DAT). The incidence of adult brown plant hopper was ranged from 2.98 to 6.20 BPH /Plot at 52 DAT, 2.76 to 7.10 BPH /Plot at 60 DAT, 2.83 to 7.39 BPH /Plot at 68 DAT and 2.92 to 7.47 BPH /Plot at 74 DAT (Figure. 1). All these cases, the highest incidence of BPH /Plot was observed in T_5 treated plot followed by T_4 treated plot and the lowest incidence was recorded in T_3treated plot followed by T_2(Figure. 1).

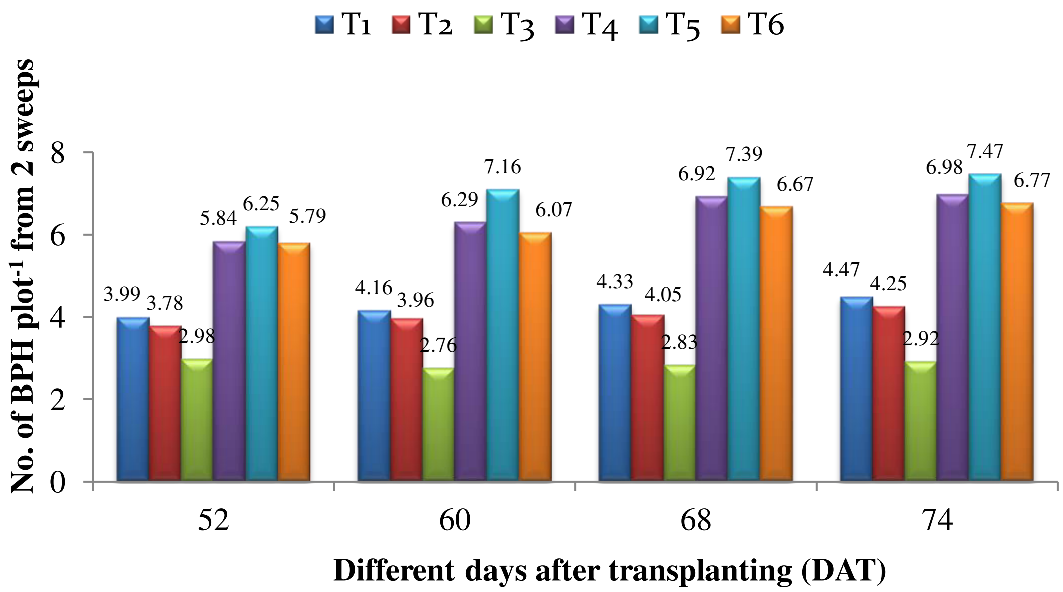


Figure 1. Effect of different doses of nitrogen on the incidence of brown plant hopper (BPH) at the reproductive stage of rice at different DAT through sweep (LSD $_{(0.05)}$ = 0.66, 0.93, 0.60 and 0.72at 52, 60, 68 and 74 DAT, respectively

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

4.2.1.2 Effect of different doses of nitrogen on the tillers infestation caused by brown plant hopper

Statistically significant variation was recorded for tillers infestation caused by brown plant hopper at reproductive stages at 65 days after transplanting (DAT) and 78 DAT (Table 4). Data recorded from 5 selected hills/plot revealed that the highest number of total tillers (29.59) was recorded from T_3 treatment which was closely followed (27.38) by T_2 treatment, while the lowest number of total tillers (20.15) was observed from T_6treatment which was followed by T_5 (22.35). In case of infested tillers, the lowest number (4.39) was found from T_3 treatment which was statistically similar to T_2 (5.59) treatment and followed (6.12) by T_1, while the highest number of infested tillers (8.40) from T_5 which was followed by T_4 (7.34) treatment and T_6 treatment (7.18).For infestation level the lowest infestation (14.04%) was recorded from T_3treated plot which was statistically similar to T_2 (20.42%) and followed by T_1(23.70%) treated plot , whereas the highest infestation (37.41%) was observed from T_5 which was closely followed by T_6 (34.44%). As a result, the Effect of different nitrogen doses among different treatment in respect of tillers infestation caused by brown plant hopper is $T_3 < T_2 < T_1 < T_4 < T_6 < T_5$.

Tiller infestation increased with increment of nitrogen levels up to 90 kg/ha because the higher presence of brown plant hopper. These results are supported by Miah and Panaullah (1999) where the application of nitrogen promoted the concentration of nitrogen in plant, as a result rice plant become more succulent and insect incidence increased. The rate of infestation was the lowest in the N control treatment T_3 of 70Kg N/ha levels (Table 2). Among the treatment, the rate of infestation was the highest in the treatment T_5 of 90 Kg N/ha levels. More nitrogen was applied in T_5 which is reflected on the reduction in number of productive tillers and result of excessive vegetative growth at different dates after transplanting. As a result brown plant hopper incidence was higher. The optimum doses of nitrogen applied in T_3, where brown plant hopper incidence was lower results as tillers infestation lowest than other (Table 4). These findings confirmed the results of Shivay and Singh (2003) where the lower incidence of insect pests was observed at 70 kg N ha (Salam *et al.*, 2004).

Table 4: Effect of different doses of nitrogen on the tillers infestation caused by brown plant hopper at different days after transplanting (DAT)

Treatment	No. of tiller at different days after transplanting (DAT)					
	65 DAT (1st observation)			78 DAT(2nd observation)		
	Total tillers (no)	Infested tillers (no)	Infestation %	Total tiller (no)	Infested tillers (no)	Infestation (%)
T_1	25.86 bc	6.12 c	23.70 c	29.55 bc	6.55 bc	22.19 c
T_2	27.38 ab	5.59 c	20.42 c	32.49 ab	5.94 cd	17.87d
T_3	29.59 a	4.39 d	14.04 d	35.03 a	4.96 d	13.69 e
T_4	24.44 bc	7.34 b	29.92 b	27.37cd	7.44 ab	27.17 b
T_5	22.35cd	8.40 a	37.41a	24.71 d	8.54 a	35.52 a
T_6	20.15d	7.18 b	34.43a	23.92 d	7.09 bc	29.71 b
LSD $_{(0.05)}$	3.64	0.91	4.15	4.03	1.33	2.93
CV (%)	8.01	7.71	8.56	7.67	10.83	6.6

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

4.2.2 Incidence of rice green leaf hopper

4.2.2.1 Incidence of rice green leaf hopper tillering stage of rice

The incidence of green leaf hopper at the tillering stage collected from different plots by sweep net through 2 sweeps was varied significantly and more or less similar trends of results in respect of the incidence of green leaf hopper were also observed through out the growing period (28, 33, 39 and 46 DAT). The incidence of green leaf hopper was ranged from 1.23 to 3.76 GLH/plot at 28 DAT, 1.78 to 4.65 GLH /plot at

33 DAT, 2.12 to 5.87 GLH /plot at 39 DAT and 2.68 to 6.83 GLH /plot at 46 DAT (Table 5). All these cases, the highest incidence of green leaf hopper was observed in T_5 treated plot which followed by T_4 and the lowest incidence was recorded inT_3 followed by T_2 treated plot at the 28 DAT, 33 DAT, 39 DAT and 46 DAT respectively (Table 5).

At tillering stage of rice plant the green leaf hopper variations of the different nitrogen doses in treatments plots where the lowest incidence in T_3 and highest incidence in T_5 and compared with untreated control in reducing the incidence of green leaf hopper than T_5 and $T_{6.}$ Optimum nitrogen application result as minimum insect incidence according to Economic threshold level (ETL). However, excess nitrogen application makes the crop succulent and enhanced lodging during grain filling stage result as sucking insect pest's incidence increased (Sidhue *et al*., 2004).

Soekhardjan *et al*. (1974) reported that in general there is an increase in the level of infestation with the increase of the age of the rice plants. Misra *et al*. (2001), Kumar and Chelliah (1986), Reddy and Misra (1996) and Soekhardjan*et al*. (1974) also gave supporting results under the present study increase of green leaf hopper.

Table 5: Effect of different doses of nitrogen on the incidence of Green leaf hopper at the tillering stage of rice plant at different DAT

Treatment	Incidence of GLH by number at different DAT			
	28 DAT (No. of GLH/2sweeps)	33 DAT (No. of GLH/2sweeps)	38 DAT(No. of GLH/2sweeps)	46 DAT(No. of GLH/2sweeps)
T_1	1.83 bc	2.63 bc	3.95 c	3.95 c
T_2	1.69 c	2.18 cd	3.31 d	3.90 c
T_3	1.23 d	1.78 d	2.10 e	2.68 d
T_4	2.08 b	2.93b	4.18 bc	5.15 b
T_5	3.76 a	4.65 a	5.87 a	6.83 a
T_6	2.05 bc	2.86 b	4.45 b	5.09 b
LSD $_{(0.05)}$	0.36	0.45	0.47	0.73
CV (%)	9.49	8.73	6.45	8.76

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

4.2.2.2 Incidence of rice green leaf hopper at reproductive stage of rice

The incidences of GLH (green leaf hopper) have been recorded throughout the growing period (52, 60, 68 and 74 DAT). treatments and the incidences were decreased with the increase of observation period except untreated control, where the incidence of GLH was increased in the following observations. Considering the pooled data, among different treatments, the highest incidence of GLH was achieved by T_5 followed by T_4, whereas the lowest reduction was achieved by T_3 followed by T_2 treatment. This trend of results was more or less similar during the observation period (Table 6). At reproductive stage the variations of the effect of different treatments as compared with untreated control in reducing the incidence of green leaf hopper by number were given below:

Table 6: Effect of different doses of nitrogen on the incidence of green leaf hopper at the reproductive stage of rice plant at different DAT

Treatment	Incidence of GLH by number at different DAT			
	52 DAT (No. of GLH/2sweeps)	60DAT (No. of GLH/2sweeps)	68 DAT (No. of GLH/2sweeps)	74 DAT (No. of GLH/2sweeps)
T_1	3.93c	4.9 c	4.66 c	4.90 c
T_2	3.35 cd	3.76 cd	3.93 cd	3.36 d
T_3	3.05 d	3.20 d	2.98 d	2.57 e
T_4	5.28 b	6.16 b	7.32 b	5.49 bc
T_5	7.14 a	8.11 a	9.06 a	7.37 a
T_6	5.07 b	6.05 b	7.12 b	5.73 b
LSD $_{(0.05)}$	0.82	0.90	1.02	0.59
CV (%)	9.76	9.4	9.6	6.58

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

Considering the different treatments, the incidence of green leaf hopper (GLH) by number was ranged from 3.05 to 7.14 GLH /plot at 52 DAT, 3.20 to 8.11 GLH /plot at 60 DAT, 2.98 to 7.78 GLH /plot at 68 DAT and 2.57 to 7.37 GLH/plot at 74 DAT. All these cases, the highest incidence of GLH was observed in T_5 followed by T_4 and the lowest incidence was recorded in T_3 followed by T_2 (Table. 6).

Alam and Razaulkarim (1976) reported GLH in Bangladesh in the years 1917, 1957, 1969 and 1976 on IR 8 and BR 3 at hard dough stage of crop with 10 to 25 populations per hill. Alam and Alam (1977) observed two outbreaks of GLH in deep water rice in 1963 from March to December and May to June.

4.2.2.3 Leaf infestation by green leaf hopper

Infestation of leaves due to green leaf hopper was greatly influenced by different treatment. The leaves infestation among different treatment was varied significantly at 39 and 58 DAT. In case of 39 DAT, the highest leaf infestation (49.22%) was recorded in T_5, which was statistically different from all other treatments. This was followed T_6 (41.88%) and T_4 (46.95%) treated plot (Table 7). On the other hand, the lowest leaf infestation (23.73%) was recorded in T_3 treated plot which was followed by T_2 (29.72%) and T_1 (32.42%). In case of 58 DAT, more or less similar trends of results were also observed, where the highest leaf infestation (44.73%) was recorded in T_5, which was followed T_6 (37.30%), T_4 (35.70%) treated plot respectively. On the other hand, the lowest leaf infestation (20.48%) was recorded in T_3 followed by T_2 (24.81%), and T_1 (28.32).As a result, the Effect of different nitrogen doses as a different treatment in respect of leaf infestation caused by green leaf hopper is $T_5 > T_6 > T_4 > T_1 > T_2 > T_3$.

Leaf infestation increased with increment of nitrogen levels up to 90 kg/ha because the higher presence of green leaf hopper. These results are supported by Miah and

Panaullah (1999) where the application of nitrogen promoted the concentration of nitrogen in plant, as a result rice plant become more succulent and insect incidence increased. The rate of infestation was the lowest in the N control treatment T_3 of 70 Kg N/ha levels (Table 7). Among the treatment, the rate of infestation was the highest in the treatment T_5 of 90 Kg N/ha levels. The optimum doses of nitrogen applied in T_3, where green leaf hopper incidence was lower results as lowest leaf infestation than other.

Table 7: Effect of different doses of nitrogen on the leaves infestation caused by green plant hopper among different treatment at different days after transplanting (DAT)

Treatment	No. of tiller at different days after transplanting (DAT)					
	39 DAT			58 DAT		
	Total tillers (no)	Infested tillers(no)	Infestation %	Total tillers (no)	Infested tillers (no)	Infestation %
T_1	23.88 ab	7.74 c	32.42 d	25.33 b	7.17 c	28.32 c
T_2	24.30 a	7.15 d	29.42 d	26.22 ab	6.50c	24.81 d
T_3	25.66 a	6.08 e	23.73 e	27.66 a	5.65 d	20.48 e
T_4	22.64 ab	8.50 b	37.53c	23.31c	8.32 b	35.70 b
T_5	19.26 c	9.44 a	49.22 a	20.58 d	9.217 a	44.73 a
T_6	21.00 bc	8.79 b	41.88 b	22.10 cd	8.247 b	37.30 b
LSD $_{(0.05)}$	3.03	0.47	3.74	2.02	0.77	2.83
CV (%)	7.3	3.25	5.76	4.59	5.6	4.88

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

4.2.3 Incidence of rice bug

4.2.3.1 Incidence of rice bug at the reproductive stage

The incidences of rice bug have been recorded throughout the growing period (55, 63, 70 and 78 DAT). The, incidences were increased with the increase of observation period except untreated control. Considering the pooled data, among different treatments, the highest incidence of rice bug was recorded by T_5 followed by T_4, here as the lowest reduction was achieved by T_3 followed by T_2 treatment. This trend of results was more or less similar during the observation period (Table 8). At reproductive stage the variations of the effect of different treatments as compared with untreated control in reducing the incidence of green leaf hopper by number were given below:

Considering the different treatments, the incidence of rice bug by number was ranged from 1.26 to 3.20 rice bugs /plot at 55 DAT, 1.75 to 5.25 rice bugs /plot at 63 DAT, 2.13 to 6.17 rice bugs /plot at 70 DAT and 2.67 to 8.08 rice bugs /plot at 78 DAT (Table 8). All these cases, the highest incidence of rice bug was observed in T_5 followed by T_4 and the lowest incidence was recorded in T_3 followed by T_2 (Table8). Rice bug, *Leptocorisa acuta* (Thunburg) and *Leptocorisa oratoria* (Fabricius) are important pests infesting the rice crop at the flowering stage. This was similarly stated by and Ito (2003) under the present study.

Table 8: Effect of different doses of nitrogen on the incidence of rice bug at the reproductive stage of rice plant at different DAT

Treatment	No. of rice bug plot^{-1} from 2 sweeps at the			
	55 DAT	63 DAT	70 DAT	78 DAT
T_1	2.32 b	3.31 c	4.16 c	5.25 b
T_2	1.94 c	2.59 d	3.56 d	4.18 b
T_3	1.26 d	1.75 e	2.13 e	2.67 c
T_4	2.51 b	3.88 b	5.04 b	7.28 a
T_5	3.20 a	5.25 a	6.17 a	8.08 a
T_6	2.44 b	3.86 b	4.99 b	7.25 a
LSD $_{(0.05)}$	0.26	0.46	0.44	1.22
CV (%)	6.15	7.42	5.54	11.63

In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.]

4.3 Yield contributing characters and yield

Yield contributing characters and yield of BRRI dhan43 showed statistically significant variation in terms of different yield contributing characters and yield of BRRI dhan43 (Table 9).

4.3.2 Number of filled grains/panicle

In consideration of number of filled grains, the maximum number of filled grains (93.38) was recorded from T_3, which was statistically similar (90.00) to T_2 and closely followed (88.65 and 85.40) by T_1 and T_4 and they were statistically similar, while the minimum number of filled grains/panicle (73.36) was found from T_6 and followed (79.43) by T_5 (Table 9).

4.3.3 Number of unfilled grains/panicle

In consideration of number of unfilled grains, the maximum number of unfilled grains (26.64) was recorded from T_6, which was followed (20.57) by T_5, whereas the minimum number of unfilled grains/panicle (6.26) was recorded from T_3 which was statistical similar (9.99) to $T_2$and followed (11.35) by T_1 (Table 9).

4.3.4 Weight of 1000-grains

1000-grain weight is an important yield contributing characters for gaining uniform yield of crop (Sing 1978) and it contributes higher performance of successful crop production (Agrikar, 1979).In consideration of weight of 1000-grains, the highest weight (28.31g) was recorded from T_3 which was statistically similar (26.23 g) to T_2 and closely followed (25.28) and 23.61 g) by T_1 and T_4 and they were statistically similar, while the lowest weight of 1000-grains (19.12 g) was found from T_6, followed (21.44) by T_5 (Table 9).

4.3.5 Grain weight per plot

In consideration of grain weight of per plot, the highest weight (2.84 kg) was recorded from T_3 which was statistically similar (2.01 kg) to T_2 and closely followed (1.93kg) by $T_1$and they were statistically similar, while the lowest grain weight of per plot (0.97 kg) was found from T_6, followed (1.11) by T_5 (Table 9).

4.3.5 Grain yield

In consideration of grains yield, the highest grain yield (4.25 t/ha) was recorded from T_3, which was statistically similar (3.19 t/ha) to T_2 and closely followed (3.01 t/ha) and 2.95 t/ha) by T_1 and $T_4$and they were statistically similar, while the lowest grain yield (1.24 t/ha) was found from T_6, followed (2.55 t/ha by T_5 (Table 9).

Table 9: Effect of different doses of nitrogen on yield contributing characters and yield of rice

Treatment	Filled grain panicle^{-1}	Unfilled grain panicle^{1}	1000 grain weight (g)	Grain weight plot^{-1} (kg)	Grain yield (t ha^{-1})
T_1	88.65 ab	11.35 d	25.28 bc	1.93 b	3.09 bc
T_2	90.00 ab	9.99 d	26.23 b	2.01 b	3.19 b
T_3	93.38 a	6.62 e	28.31 a	2.84 a	4.25a
T_4	85.40 bc	14.6 c	23.61c	1.31c	3.01 cd
T_5	79.43 cd	20.57b	21.44d	1.11cd	2.55 d
T_6	73.36 d	26.64 a	19.12e	0.97 d	1.24e
LSD $_{(0.05)}$	7.42	2.08	1.98	0.29	0.55
CV (%)	4.8	7.65	4.54	9.43	9.54

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 3 replications

[T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application; T_6 = Untreated control.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from April to August 2016 to evaluate the effect of different doses of nitrogen fertilizer (urea) on the incidence of sucking insect pests of rice. BRRI dhan43 were used as test crop in this experiment. The experiment comprised of the following nitrogen doses as treatment- T_1 = Top dressing of Nitrogen fertilizer (urea) @ 50kg/ha at three equal split application; T_2 = Top dressing of Nitrogen fertilizer (urea) @ 60kg/ha at three equal split application; T_3 = Top dressing of Nitrogen fertilizer (urea) @ 70kg/ha at three equal split application; T_4 = Top dressing of Nitrogen fertilizer (urea) @ 80kg/ha at three equal split application; T_5 = Top dressing of Nitrogen fertilizer (urea) @ 90kg/ha at three equal split application and T_6 = Untreated control. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data was recorded on pest incidence, number of healthy, infested plants & leaf for different pests and infestation level an also yield contributing characters and yield of BRRI dhan43 and significant variations was observed for different treatments.

Under the present experiment 3 common species of sucking insect pests were found and they belong to 3 families under 2 orders. Among the recorded insect pests 1 species belong to the family Delphacidae, 1 species belong to the family Cicadellidae and another one species belong to the family Alydidae (Coreidae). Insect population for 5 selected hills/plot were observed with clean observation and in the experimental plot brown plant hopper, green leaf hopper and rice bug was observed and the highest number of theses insect pests was recorded from T_5, whereas the lowest number of these insect pests was observed from T_3 treatment. In case of brown plant hopper incidence at vegetative stage the lowest incidence (3.64, 4.57, 5.09, 5.48 and 5.81) was recorded from T_3, whereas the highest incidence of BPH at the 28 DAT, 33 DAT, 38 DAT, 43 DAT and 48 DAT (9.34, 11.07, 12.90, 13.26 and 14.120 respectively) were observed from T_5. At reproductive stage, incidence of brown plant hopper at the 52 DAT, 60 DAT, 68 DAT and 74 DAT; the lowest incidence (2.98, 2.76, 2.83, and 2.92 respectively) was recorded from T_3, whereas the highest incidence (6.20, 7.10, 7.39 and 7.46 respectively) was observed from T_5.

In case tillers infestation caused by brown plant hopper at vegetative stages the lowest infestation (4.39% and 4.96%) was recorded from T_3, whereas the highest infestation (37.41% and 35.52%) was observed from T_5 at the 65 DAT (1^{st} observation) and 78 DAT(2^{nd} observation) respectively.

In leaves infestation of rice due to green leaf hopper the lowest infestation (23.73% and 20.48%) was recorded from T_3, whereas the highest infestation (49.22% and 44.73%) was observed from T_5. In leaf infestation of rice caused by green leaf hopper the lowest leaf infestation (3.59%) was recorded from T_3, whereas the highest leaf infestation (15.13%) was observed from T_5 at the 39 DAT and 58 DAT respectively. At the tillering stage, the incidence of green leaf hopper was ranged from 1.23 to 3.76, 1.78 to 4.65, 2.12 to 5.87 and 2.68 to 6.83 numbers of GLH /plot at 28 DAT, 33 DAT, 39 DAT and 46 DAT respectively. On the other hand at reproductive stage incidence of green leaf hopper was ranged from 3.05 to 7.14, 3.20 to 8.11, 2.98 to 7.78 and 2.57 to 7.37 number of GLH/plot at the 52 DAT, 60 DAT, 68 DAT and 74 DAT respectively. All these cases, the highest incidence of GLH was observed in T_5 followed by T_4 and the lowest incidence was recorded in T_3 followed by T_2. The leaves infestation due to green leaf hopper among different treatment was varied significantly at 39 and 58 DAT. In case of 39 DAT, the highest leaf infestation (49.22%) was recorded in T_5, which was statistically different from all other treatments. This was followed T_4 (41.88%) and T_6 (46.95%) treated plot (Table 7). On the other hand, the lowest leaf infestation (23.73%) was recorded in T_3 treated plot which was followed by T_2 (29.72%) and T_1 (32.42%). In case of 58 DAT, more or less similar trends of results were also observed, where the highest leaf infestation (44.73%) was recorded in T_5, which was followed T_6 (37.30%), T_4 (35.70%) treated plot respectively. On the other hand, the lowest leaf infestation (20.48%) was recorded in T_3 followed by T_2 (24.81%), and T_1 (28.32).As a result, the Effect of different nitrogen doses as a different treatment in respect of leaf infestation caused by green leaf hopper is $T_5 > T_6 > T_4 > T_1 > T_2 > T_3$.

At reproductive stage the incidence of rice bug by number was ranged from 1.26 to 3.20, 1.75 to 5.25, 2.13 to 6.17 and 2.67 to 8.08 numbers of rice bugs /plot at 55 DAT, 63 DAT, 70 DAT and 78 DAT. All these cases, the highest incidence of rice bug was observed in T_5 followed by T_4 and the lowest incidence was recorded in T_3 followed by T_2

In consideration of yield contributing characters and yield of BRRI dhan43, the maximum number of filled grains/panicle (93.38%) was recorded from T_3, while the minimum number of filled grains/panicle (73.36%) from T_5. The maximum number of unfilled grains (20.57%) was recorded from T_5, whereas the minimum number of unfilled grains/panicle (6.62) was recorded from T_3, The highest 1000-grain weight (28.31 g) was recorded from T_2, while the lowest weight of 1000-grains (19.12 g) was found from T_5. The highest grain yield (4.25 t/ha) was recorded from T_3, while the lowest grain yield (1.24 t/ha) from T_5.

Considering yield and yield contributing characters, optimum nitrogen fertilizer doses 70kg N /ha applied in T_3 (4.25 t/ha) was superior to the other nitrogen doses and at 60 kg N/ha applied in T_2 (4.19 t/ha) that was second highest of all treatment.

CHAPTER VI

REFERENCES

Abd-El -Hafez, A.A. (2001). Comparison of quality attributes and life table parameters of four trichogrammatids (Hymenoptera: Trichogrammatidae) reared from Pectinophra gossypiella (Saund.) eggs. *Arab Uni. J. Agril. Sci.***9** (1): 411-421.

Ahmad, S., Hussain, A., Ali, H. and Ahmad, A. (2005).Grain yield of transplanted rice (*Oryza sativaL.*) as influenced by plant density and nitrogen fertilization. *J. Agric. Social Sci.* **1**:212-215.

Ahmad S, Zia-ul-Haq M, Ali H, Ahmad A, Khan MA, Khaliq M, Husnain Z, Hussain A, Hoogenboom G (2009). Morphological and quality parameters of *Oryza sativa L.* as affected by population dynamics, nitrogen fertilization and irrigation regimes. *Pakistan J. Bot.***41** (3):1259-1269.

Ali A, Karim MA., Hussain G., Ali L., Ali SS., Majid A (1992). Rice grain quality influenced by split application of nitrogen fertilizer. *Int. Rice Res. Newsl.***17** (3):7-11.

Alam, S., (1983). Current application methods of insecticides in rice farmers fields in Bangladesh. FAO/IRRI workshop on judicious and efficient use of pesticides on rice. *IRRI, the Phillipines.*19p.

Alam, S., Karim, A. N. M. R., Alam, M.S. and Nurullah, C.M. (1983). Important rice insect pests control transfer able to farmer's fields. In: Proc. Workshop on Modern Rice Cultivation in Bangladesh, BRRI, Gazipur. pp. 106-116.

Alam, S., (1971). Population dynamics of the leafhopper and planthopper pests of rice. Ph.D. Thesis, Cornell University, USA. 141p.

Alice and Sujeetha (2001). The effect of 7 rice cultivars on the population of rice brown plant hopper (BPH), *Nilaparvata lugens*. *Environ. Entomol.* **13**: 1271-1278.

Ambkadevi, I.S., Valencia, S.L. and Chelliah, C. (1998). Incidence of White backed plant hopper *Sogatella furcifera* Guen. On paddy in Haryana.*India J. Entol.* **49**(4): 465-467.

Andrews, D.J. (1972). Yield performance on cereal crops – a biological cooperative. *Shanura Agri. News*. **13**(2): 22 - 25.

Anonymous (2013). Economic Survey, Economic Affairs Division, Govt. Pakistan, Islamabad. Ashraf M, Khalid A, Ali K (1999). Effect of seedling age and density on growth and yield of rice in saline soil. *Pakistan J of Bio Sci***2**:860-862.

BARI(1989). Annual Report (1988-890). Plant pathology division, Bangladesh Agricultural Research Institute, Joydebpur.pp. 50.

Barr. B.A.S and Smith.R.F.(1975).Crop loss to insects, diseases and other pests.USAID, Pestmanagement and related environmental protection project.University of California, Berkley. 64 p.

BBS (Bangladesh Bureau of Statistics), Bangladesh (2004) Stat. Div. Mins.Agriculture, Govt. People's Repub. Bangladesh, Dhaka. P. 211.

Biswas, P.K. and Islam, N. (2012).Incidence of insect pest in rice.Bangladesh *J.Agri. Res*., **37**(1): 19-25.

Biswas, S.K., B. Banu, K.A. Kabir, F. Begum and N.H. Choudhury. 1992. Physicochemical properties of modern and local rice varieties of Bangladesh. *Bangladesh Rice J*. **3**(1&2): 128-131.

BRRI (Bangladesh Rice Research Institute). 2002. Annual Internal Review held on 22 December-26 December, Soil Sci. Divn, *Bangladesh Rice Res. Inst. Gazipur. pp*. **3-6**, 25-26.

BRRI (Bangladesh Rice Research Institute). 2004. Annual Internal Review held on 26 December - 29 December, Soil Science Divn. *Bangladesh Rice Res. Inst. Gazipur, pp.* 1, 50.

BRRI (Bangladesh Rice Research Institute) (1985). Dhan Chaser Samashya BRRI, 1985.Annual Report for 1984.*Bangladesh Rice Research Institute Gazipur*, 207p.

Chakraborty, D.P., Sirvastava, P.C., Ghose, G.C., Maslen, N.R., Holt, J.and Flower, S.V. (1990). Rice pest abundance in Bihar and Orissa States, India.*Int.Rice Res.News*. **15**(4):26-27.

Chakroborti, S., (2003). Management of insect pests in deep water rice usingecofriendly approach. J. *App Zoo Res*., **14**(1): 65-67.

Chaudhry FM., Kausar MA, Rashid A (1977). Mechanism of nitrogen effect on zinc nutrition of flooded rice. *Plant Soil* **46** (3):649-654.

Chen, C.C., and Chu R.J. (1981). Rice wilted stunt in Taiwan. Intl. *Rice Res. News*. **6**(1): 13.

Cheng C H, Pathak M D (1972) Resistance to ephotettix virescens in rice varieties. *J. Econ. Entomol.* **65**:1148-1153.

Colwell, J.D., 1994.Estimating Fertilizer Requirements.A Quantitative Approach. CAB International. Walliningford, Oxon-OX1O 8DE. UK. pp. 34-64.

Cook, A.G., and Perfect, T.J. (1989). Population dynamics of three leafhopper vectors of rice tungro viruses, *Nephotettix virescens* (Distant), N. *nigropictus* (Stal) and *Recilia dorsalis* (Motschulsky) (Hemiptera: Cicadellinae), in farmers' fields in the philippines, Bull. *Entomology. Res.***79** (3): 437-451.

Das, K., and Sarma, A.K., (1956).Varietal response of rice to date of sowing and levels of fertilization. *J. Sci. Res. Banaras*. **6**(2): 236-250.

Ding, C., You, J., Chen, L., Wang, S., Ding, Y., (2014). Nitrogen fertilizer increases spikelet number per panicle by enhancing cytokinin synthesis in rice. *Plant Cell Rep* **33**(2):363-71.

Dobermann A, Cassman KG (2002). Plant nutrient management for enhanced productivity in intensive grain production systems of the United States and Asia. Plant Soil **247**:153-175.

Everett T R (1967) Vectors of hoja blanca virus. Pages 11-12, in the virus diseases of the rice plant. **124**:101-132.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. *People'sRepublic of Bangladesh*.p.118.

Emmanuel, M., Alam, S., and Karim, Ahmed, M.S. (2003).Varietal response of rice against white bucked plant hopper.*Indian J. Entomol*., **61**(3): 169-178.

FAO (Food and Agriculture Organization).(1988). Production Yearbook for 1998. FAO, UN. Rome, Italy. p. 118.

FAO (Food and Agriculture Organization). (2009). FAO Production Yearbook, Food and Agriculture Organization, Rome, Italy.56-77.

Fageria NK, Santos AB, Cutrim VA (2008).Dry matterand yield of lowland rice genotypes as influence by nitrogen fertilization. J Plant Nut **31**(4):788-795.

Godase, S.K. and Dumbre R.B. (1982). Laboratory studies on bionomics of rice leaf roller, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Pestology*, **6**: 13–16.

Gomez K.A. Gomez A.A., (1984). Statistical procedure for agricultural research. International Rice Research Institute. *John Wiley and Sons*, New York, 139-240.

Gupta, T.R. and Saini, J.S., (1982).Effect of sowing dates and time of nitrogen application on seed and oil yield of Toria.*Indian J. Agron***. 27**(4):326-329.

Haque, M.A. and Islam, B.N., (1988).Effect of methanolic neem and chinaberry seeds extract on rice green leaf hopper, *Nephotettix nigropictus.Bangladesh J. Agril.***13**(10): 53-57.

Hariprasad, Y. (1999). Studies on host plant resistance against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) P^hD. Thesis, Annamalai University,Annamalai nagar India. P. 259.

Harish, K., (1995). Varietal resistance, population dynamics and timing insecticidal application with peak oviposition by *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae) on rice. *Annals of App. Biol.,***127**(2): 221-228.

Haque, M.A., Q.A. Khaliq, A. Karim, J.U. Ahmed and M.H. Rahman. 2004. Nitrogen fertilizer effect ondry matter production and grain growth and aromatic rice. J. Subtrop. *Agric. Res. Dev*. **2**(2): 15-19.

Heinrichs, E.A., Rapusas, H.R., Aquine. G.B. and Polls, F. (1982). Integration of host plant resistance and insecticides in the control of Nephotettix virescens (Homoptera: Cicadellidae) a vector of rice tungro virus. *J. Econ. Entomol.***79**: 437-443.

Heinrichs, E.A., Reising, W.H., Valencia, S.L. and Chelliah, C. (1985). Rules and effects of resurgence inducing insecticides on population of brown plant hopper, Nilaparvata lugens stal. and its predators. *Environ. Entomol*. **11**: 1269-1273.

Hernandez J E, Khush G S (1981) Genetics of resistance to whitebacked planthop- per in some rice varieties. *Oryza* **18**:44-50.

Heinrichs, E.A., Reessing, W.H., Valencia, S. and Chelliah, S. (1985). Rates and effect of resurgence inducing insecticides on populations of *Nilaparvatalugens* (Homoptera: Delphacidae) and its *predators. Entomol.***11**: 1269-1273 p.

Hien, N.L., Yoshihashi, T., and Sarhadi, W.A. (2006).Evaluation of aroma in rice using KOH method, molecular markers and measurement of 2-acetyl-1-pyrroline concentration. *Japanese J. Trop. Agric*., **50**: 190-198.

Hibino, H., (1979). Rice ragged stunt, a new virus disease occurring in tropical Asia. *Rev. Plant Prot. Res.* **12:** 98-120.

Hiesh, C.Y. (1972). Population ecology of the rice green leaf hopper *Nephotettix virescens*. M.S.Theis, University of Philippines.

Hinckley, A.D. (1963). Ecology and control of rice plant hopper. *Entomol. Res***. 4**: 467-481.

Jennings P R, Pineda A T (1970a) Effect of resistant rice plants on multiplication of the planthopper, *Sogatodes orizicola* (Muir). Crop Sci. **10**:689-690.

Jennings P R, Pineda A.T. (1970b) Screen- ing rice for resistance to the planthopper, *Sogatodes oryzicola* (Muir). Crop Sci. **10**:687-689.

Kapur, A..P. (1967).The major insect pests of rice plants.In Proc. Symp. Int. Rice. Res. *Inst. IRRI, Philippines*, pp. 3-43.

Kamran, M.A. and Raros, E.S. (1967). Seasonal fluctuation in abundance ofvarious rice stem borer on Luzon Island, The Phillippines. *J. Econ. Entomol.* **61**(3):650- 665.

Kapur, A.P. (1967).The major insect pests of rice plants.In Proc. Symp. Int. Rice. Res. Inst. IRRI, Philippines, pp. 3-43.

Karim, A.N.M.R.(1986). The hispa espisode.Modern rice cultivation workshop, Bangladesh Rice Research Institute, Joydepur. pp. 125-160.

Kaushik, D.C., Tripathi, N.N. and Satyavir.(1978). Effect of date of sowing of Toria on phyllody incidence and estimation of losses.Haryana Agric University. *J. Res.***8**(1): 28-30.

Kaushik, D.C., Tripathi, N.N. and Satyavir.(1978). Effect of date of sowing of Toria on phyllody incidence and estimation of losses.

Khan A.N., Malik, S.S., and Chhillar, B.S. (1989).Research on pyralids and gelechiids at Bangladesh Rice Research Institute (BRRI), Entomology Division, BRRI, Jydebpur, Gazipur, Bangladesh.163 p.

Khan, M., Hameed, S.F. and Mehto, D.N. (1989). Yield performance on cereal crops – a biological cooperative. *Shanura Agric. News*. **15**(2): 27 - 30.

Khush, G.S. (1997). Origin dispersal, cultivation and variation of rice. *Plant Mol. Biol*. **35**:25-34.

Kim, H.S., Heinrichs, E.A. and rapusas, H.R. (1986).Levels of resistance of rice cultivars and the weed Leesia hexandra l. to Nephotettix malayanusand N. virescens (Distant). *Crop Prot.* **5**(6):400-405.

Khan Z R, Saxena R C (1984) A selected bibliography of the whitebacked planthopper *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae). *Insect Sci. App***. 6**:115-134.

Khan Z R, Saxena R C (1985) Mode of feeding and growth of Nephotettix virescens (Homoptera: Cicadellidae) on selected resistant and susceptible rice varieties. *J. Econ. Entomol.***78**:583-587.

Kisimoto R (1965) Studies on the poly- morphism and its role playing in the population growth of the brown planthopper *Nilaparvata lugens* Stål Bull. Shikoku Agric.*Exp.Stn*. 13:106

Kisimoto.R.(1965). Studies on the polymorphism and its role in the population growth. Bull-Skikoku Agric. *Exp. Sta. pp*. 131-106.

Koral, S., Kamran, M.A., and Raros, E. S. (1998).Screening for resistance to different insect pests.IRRI. **10** (2):6.

Kumar, M., R.P Singh and N.S Rana. 2003. Effect of organic inorganic sources of nutrition on productivity of rice (Oryza sativa). *Indian J. Agron*. **48**(3): 175-177.

Liu, X. (1995).New hybrid rice for late season. *Chinese Rice Res. News*., **3**(2): 12.

Mannan.M.A. and S.D. Siddique. 1991. Effect of seedling age and date of planting on the growth and yield of photoperiod sensitive rice. Bangladesh Rice J. **2**(1 & 2): 2004- 206.

Miah, M.A.M. and G.M. Panaullah.1999.Effect of water regimes and N-levels on soil available N, its uptake and use efficiency by transplanted rice. Bangladesh *J. Agril. Res.***24**(2): 343-3 53.

Moriwaki, T. 1999. On the ideal culm elongation in rice plants (3).Nogyogijyutu **54**:133- 138 (In Japanese).

Nath, P. and Bhagabati, K.N. (2005). Population dynamics of leaf hopper vectors of Rice tungro virus in Assam. *Indian Phytopatho.,* **55**(1): 92-94.

Noda (1987).Rice pest abundance in Bihar and Orissa States, India.Int. *Rice Res. News*. **15**(4):26-27.

Nugaliyadde, N. (1994). Factors associated with the resistance of rice (Oriza sativa L.) to *Nilaparvata lugens* stal. Ph.D. Thesis, University of Newcastle upon Tyne, England.p. 163.

Oudhia, S.R., Roa, J. and Gupta, A. (1999).Evaluation of the response of 9 hybrids and one local variety of rice to brown plant hopper, *Nilaparvata lugens*. *J. Econ. Entomol*. **79**: 437-443.

Pandats, S., Ghose, G.C. and Maslen, N.R (1990). Study on the fluctuation of green leafhopper population in relation to age of rice crop. India*. Int. Rice Res. News.**13***:19-21.

Patana kamjorn and Pathak (1967). Evaluation of significant relationship between the degree of infestation and yield attributes. *India J. Entol*. **44**(3): 452-457.

Pillayar, P. (1988). Rice Pest Production Manual, Wiley Eastern Ltd., New Delhi, 437p.

Quing M.P. and Biswas, K.P. (2000).Relative abundance of different species of white backed plant hopper in deep water rice in north Bihar.Oryza.International Rice *Res. News*. **26**(3): 282-284.

Roy, B.C., D.E. Leihner, T.H. Hilger and N.Steinmueller. 2004. Tillering pattern of local and modern T. Aman varieties as influenced by nitrogen rate and management practices. *J. Subtrop. Agric. Res. Dev.***2**(2): 6-14.

Rice Research Institute, Philippines, April 1967. The Johns Hopkins Press, Baltimore, Maryland.

Razzaque, Q.M.A., Heinriches, E.A. and Rapusas, H.R. (1985).Mass rearing technique for rice green leaf hopper *Philipines Entomol.***6**(4): 398-404.

Reddy.K.D. and Misra.D.S. (1995). Varietal response of rice against brown plant hopper *Nilaparvaia .indian J. Entomol.***57**(3): 169-178.

Reissig, W., Heinrichs, E.A., Litsinger, J.A., Mooders, K., Fiedler, L., Mews, T. W. and Barrion, A.T. (1985). Hustrated guide to Integrated Pest Management in Rice in Tropical Asia. IRRI, Philippines.79p.

Salam, M.A., F. Ali, M.P. Anwar and M.S.U. Bhuiya. 2004. Effect of level of nitrogen and date of transplanting on the yield and yield attributes of transplanted Aman rice under SRI method. *J. Bangladesh Agril. Univ*. **2**(1): 3 1-36.

Saleque. M.A., U.A. Nahar, N.N. Choudhury and A.T.M.S. Hossain 2004.Varietyspecific nitrogen fertilizer recommendation for low land rice. *Comm. Soil Sci. Plant Anal.* ***35:*** *189 1-1903.*

Sharma, A.R. and D.P. Singh. 1999. Rice. Crop Yield Physiology and Process.Springerverlag Berlin. Heidelberg: Editors. Smith, D.L. and C. Hamel.pp.109-138.

Singh, C.S. and Singh, U.N. 2002. Effect of N and S nutrition on growth and yield of rice cultivars. *Res. Crops*. **3**(3): 643-645.

Shivay, Y.S., and S. Singh. 2003. Effect of planting geometry and nitrogen level on growth, yield and nitrogen use efficiency of scented hybrid rice (*Oryza sativa*). *Indian J. Agron*. **48**(1): 42-44.

Sidhue, M.S., R. Sikka and T. Singh. 2004. Performance of transplanted Basmati rice in different cropping systems as affected by N application. *Intl. Rice Res. Note***29**(1): 63-65.

Teng, S.k., Rasiogi, A.K., and Singh, B.M. (1993). Population dynamics of rice sting bug, *Leptocorisa varicornis* in relation to weather factor. *Indian, J. Agric. Sci*. **37**(2): 112-119.

Tsueda, H., Yajima, M. Taguchi, Y. and Suzuki, T. (2002). Occur rent tendency of rice sting bugs in South flat area of Gifu Prefecture. Proc. *The Kansai Plant Protection Soc.* **4**: 13-20.

Velusamy, R., (1988). Resistance of wild rices, Oryza sativa, to brown plant hopper, *Nilaparvata lugens* stal. (Homoptera: Delphacidae). *Crop Prot*. **7**(6): 403-408.

Venkateswarlu, C., Viraktamath, C.A. and Sathyanayana, J. (2002). The 100 rice cultivars screened to leaf folder infestation, only twenty- two showed a consistent damage. *Indian, J. Agric. Sci*. **41**(2): 112-119.

Wahiduzzaman, M., (1993).Studies of the insect predatory behavior of the blackdrongo in rice ecosystem M.S thesis, Institute of Post Gratuate, Delhi, India.

Woodhead, S. and Padgham, E.E. (1988).The effect of plant surface characteristics on resistance of rice to brown plant hopper, *Nilaparvata lugens* Stal. *Entomol. Exp. App*. **47**:15-22.

Wu, S., Zhang L.Y. and Yang, X.Q. (1980).Evaluation of modified seedling bulk-screening test for resistance to brown plant hopper, *Nilaparvata lugens* in cultivated and wild rice. *J. South-China Agric. Univ*. **17**(1): 77-81.

Yoshida, S. 1981. Fundamentals of Rice Crop Science.Intl Rice Res. *Inst., Los Banos, Philippines. pp.***41-**248.

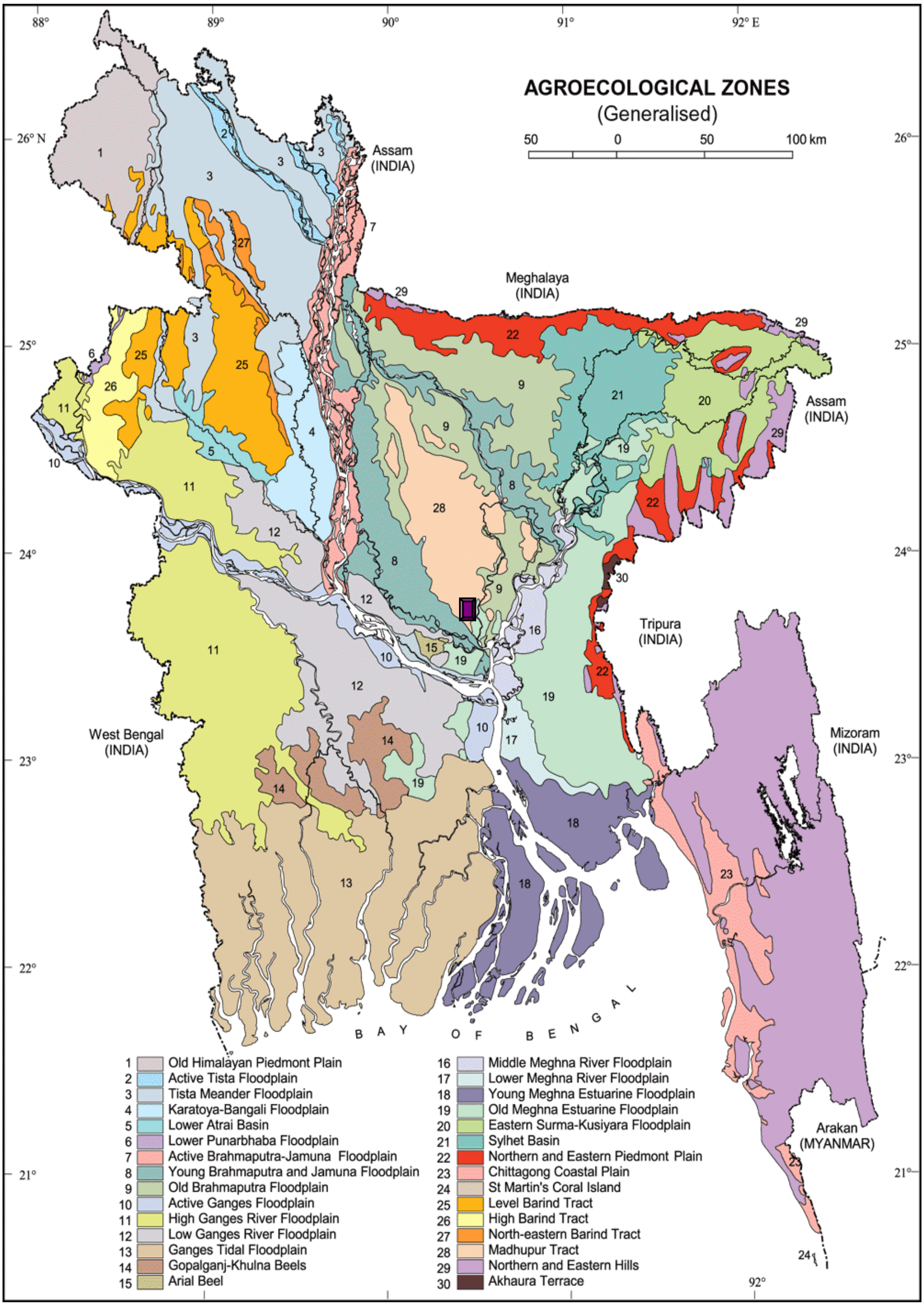
Yasumatsu and Torii, 1968). Pest management and related environmental protection project. University of California, Berkley. 64p.

Zhang L.Y., Wu, R.Z., and Yang, X.Q. (1994). Evaluation of the resistance of new rice lines Hong-Yuan and Tainuo-Xuan to the brown plant hopper, *Nilaparvata lugens.J. South-China Agric. Univ*. **15**(2): 67-72.

CHAPTER VII

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from April to August 2016

Month (2016)	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
April	34.2	23.4	61	128
May	34.7	25.9	70	289
June	35.4	22.5	80	427
July	36.2	24.6	83	553
August	36.0	23.6	81	312

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Characteristics of the soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.7
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix IV. Analysis of variance of the data on the incidence of Brown plant hopper at the vegetative stage of rice plant at different DAT through sweep as affected by different nitrogen levels

Source of variation	df	Mean square value of incidence of Brown plant hopper at different DAT				
		28	33	39	46	52
Replication	2	0.13	0.24	0.06	0.19	0.24
Nitrogen levels	5	2.39*	3.84*	5.25*	6.89*	8.67*
Error	10	0.07	0.09	0.15	0.20	0.25

*Significant at 5% level of significance
NS Non significant

Appendix V. Analysis of variance of the data on the incidence of brown plant hopper (BPH) at the reproductive stage of rice at different DAT through sweep as affected by different nitrogen levels

Source of variation	df	Mean square value of incidence of Brown plant hopper at different DAT			
		58	66	72	78
Replication	2	0.11	0.10	0.40	0.54
Nitrogen levels	5	5.41*	8.38*	10.52*	10.13*
Error	10	0.13	0.26	0.11	0.16

* Significant at 5% level of significance
NS Non significant

Appendix VI. Analysis of variance of the data on the incidence of tillers infestation caused by Brown plant hopper among different treatment at different days after transplanting (DAT) through sweep

Source of variation	df	Mean square value of					
		65 DAT			78 DAT		
		Total tillers	Infested tillers	Infestation	Total tillers	Infested tillers	Infestation
Replication	2	4.73	0.16	1.20	9.62	0.29	0.15
Nitrogen levels	5	34.96*	6.12*	236.20*	57.35*	4.62*	193.04*
Error	10	3.99	0.25	5.20	4.90	0.54	2.59

*Significant at 5% level of significant
NS Non significant

Appendix VII. Analysis of variance of the data on the incidence of Green leaf hopper (GLH) at the tillering stage of rice at different DAT through sweep as affected by different nitrogen levels

Source of variation	df	Mean square value of incidence of Green leaf hopper at different DAT				
		28	32	39	46	52
Replication	2	0.04	0.070	0.61	0.50	0.58
Nitrogen levels	5	2.25*	2.93*	4.71*	6.08*	7.67*
Error	10	0.04	0.06	0.07	0.16	0.21

*Significant at 5% level of significance
^{NS} Non significant

Appendix VIII.Analysis of variance of the data on the incidence of Green leaf hopper at the reproductive stage of rice plant at different DAT through sweep as affected by different nitrogen levels

Source of variation	df	Mean square value of incidence of Green leaf hopper at different DAT			
		58	66	72	78
Replication	2	0.02	0.03	0.07	0.46
Nitrogen levels	5	6.94*	10.18*	16.48*	8.95*
Error	10	0.21	0.25	0.32	0.10

* Significant at 5% level of significance
^{NS} Non significant

Appendix IX.Analysis of variance of the data on the incidence of leaves infestation caused by green plant hopper among different treatment at different days after transplanting (DAT) through sweep

Source of variation	df	Mean square value of					
		39 DAT			58 DAT		
		Total tillers	Infested tillers	Infestation	Total tiller	Infested tillers	Infestation
Replication	2	11.59	1.78	17.52	23.18	1.21	30.03
Nitrogen levels	5	16.41*	4.45*	250.78*	21.39*	5.21*	241.02*
Error	10	2.77	0.07	4.22	1.24	0.18	2.43

*Significant at 5% level of significance
^{NS} Non significant

Appendix X. Analysis of variance of the data on the incidence of Rice bug at the reproductive stage of rice plant at different DAT through sweep as affected by different nitrogen levels

Source of variation	df	Mean square value of incidence of Rice bug at different DAT			
		55	63	70	78
Replication	2	0.10	0.05	0.38	0.39
Nitrogen levels	5	1.25*	4.35*	5.87*	13.33*
Error	10	0.02	0.07	0.06	0.45

* Significant at 5% level of significance
^{NS} Non significant

Appendix XI. Analysis of variance of the data on the yield contributing characters and yield of rice

Source of variation	df	Mean square value of				
		Filled grain panicle^{-1}	Unfilled grain panicle^{1}	1000 grain weight	Grain weight plot^{-1}	Grain yield
Replication	2	256.72	2.07	18.59	0.02	0.06
Nitrogen levels	5	165.12*	165.18*	33.43*	1.49*	4.38*
Error	10	16.63	1.31	1.19	0.03	0.09

* Significant at 5% level of significance
^{NS} Non significant