Relationship between phenological stages of boro rice and the stages of life cycle of yellow rice stem borer (*Scirpophaga incertulas*) in fields

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DECLARATION

The whole work submitted as a thesis entitled "Relationship between phenological stages of boro rice and the stages of life cycle of yellow rice stem borer (*Scirpophaga incertulas*) in fields" in the Department of Zoology (Environmental Biology and Biodiversity Laboratory) University of Dhaka for the award of the Degree of Doctor of Philosophy is the results of my own investigation during the years 2010-2014. The research work was carried out under the supervision of Dr. M. A. Bashar, Professor, Department of Zoology, University of Dhaka and Dr. Reza Md. Shahjahan, Professor, Department of Zoology, University of Dhaka. This thesis has not been submitted in any form to any other University for any degree.

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CERTIFICATE

This is to certify that the thesis entitled "Relationship between phenological stages of boro rice and the stages of life cycle of yellow rice stem borer *(Scirpophaga incertulas*) in fields" is the record of basic research carried out in Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka, Bangladesh. All the data, figures and parts presented in this thesis are original and based on his observation. The research work has not previously submitted elsewhere for any other degree or diploma

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MY BELOVED PARENTS

BIOGRAPHICAL SKETCH

The author was born on 10, April 1976 at Charbadrasion in the district Faridpur. He comes of a respectable and enlightened Muslim family. He passed the Bachelor of Science Exam. in Agriculture in 1998 and Master of Science in Agricultural (Agronomy) in 2001 from the Bangladesh Agricultural University (BAU), Mymensingh. As a student of Bachelor of Science in Agriculture and Master of Science in Agriculture in Agronomy he enjoyed the University stipend for pursuing his degrees. He was an overall champion in Table Tennis and awarded the certificate of best player in Football and Volleyball several times in his College and University life. The author is awarded a best presentator certificate on "Biodiversity conservation through open butterfly colonization" at Asia- Plant Science Conference held in Nepal (November, 2014) during his Ph.D study.

He started his service career as a Biology teacher at the ABC International School (O & A level) in the year 2005. At present he is acting as an assistant vice principal, Head of the Department of Biology and student Counselor at the same institute. A good number of students achieved world highest and country highest marks at O & A level exam. in different subjects as well as secured scholarship at different renown Universities in USA, Australia, Canada, Newzealand and Malaysia under his direct teaching and supervision. The author received a remarkable number of certificates as an excellent performer in O & A level Biology teaching under the Edexcel, British Council.

The author was awarded an in country scholarship by the Ministry of Information, Communication & Technology, Bangladesh in 2010 and 2012 to pursue a Ph. D degree programme in Entomology, Department of Zoology, University of Dhaka, Dhaka.

He is a founder general secretary of Biodiversity Conservation Trust Foundation (BCTF) and Ex-officio member of Journal of Biodiversity Conservation and Bioresource Management. He is a life member of Krishibeed Institution and Zoological Society of Bangladesh. He has four research publications in the journals.

He is married to Tahmina Begum and is blessed with a son, Mobasshir Bin Moula.

LIST OF ABBREVIATIONS

A&E	=	Adult and egg
a.i	=	active ingredient
A	=	Adult
AEZ	=	Agro Ecological Zone
AT	=	Active tillering
BADC	=	Bangladesh Agricultural Development Corporation
BCTF	=	Biodiversity Conservation Trust Foundation
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
BSMRAU	=	Bangabandhu Sheikh Mojibur Rahman Agricultural University
CGR	=	Crop growth rate
CV	=	Coefficient of Variance
cv	=	Cultivated variety
DAH	=	Days after heading
DAI	=	Days after infestation
DAS	=	Days after sowing
DAT	=	Days after transplanting
DH	=	Dead heart
DMRT	=	Duncan's Multiple Range Test
DW	=	Dry weight
E A	=	Early April
E	=	egg
EBBL	=	Environmental Biology and Biodiversity laboratory
EF	=	Early February
EJ	=	Early January
EM	=	Early March
ERS	=	Early reproductive stage
F	=	Flowering
$g\ m\text{-}^{2}d^{-1}$	=	Gram per meter square per day
HI	=	Harvest index
$Hill^{-1}$	=	Per hill
HS	=	Heading stage
I_n	=	Natural logarithm
IPM	=	Integrated pest management
IRRI	=	International Rice Research Institute
IT WAS	=	Infested tiller without appearing any symptom
L	=	Larva
LA	=	Late April
LA	=	Total leaf area
LA_1	=	Total area at time T_1

LA_2	=	Total area at time T_2
LAI	=	Leaf area index
LEP	=	Late filing period
LF	=	Late February
LIP	=	Linear increasing phase
LJ	=	Late January
LM	=	Late March
LSD	=	Least significance difference
M	=	Maturity
MA	=	Mid April
MM	=	Mid may
MF	=	Mid February
mg grain-1 d-1	=	Milligram per grain per day
MJ	=	Mid January
MM	=	Mid March
MS	=	Maturity stage
MTS	=	Maximum tillering stage
NAR	=	Net assimilation rate
NS	=	Not significant
P	=	Pupa
Panicle $^{-1}$	=	Per panicle
PF	=	Pre flowering
PIS	=	Panicle initiation stage
PL	=	Panicle length
PRS	=	Post reproductive stage
RGR	=	Relative growth rate
RS	=	Reproductive stage
S	=	Seedling
SB	=	Stem borer
SLW	=	Specific leaf weight
t ha $^{-1}$	=	Ton per hectare
T_1	=	First time
T_2	=	Final time
TDM	=	Total dry matter
VS	=	Vegetative stage
W_1	=	Total dry weight at time T_1
W_2	=	Total dry weight at time T_2
Week^{-1}	=	Per week
WH	=	White head
YSB	=	Yellow rice stem borer

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ABSTRACT

An experiment was carried out to evaluate the "Relationship between phenological stages of boro rice and the stages of life cycle of yellow rice stem borer (S*cirpophaga incertulas*) in fields" at the experimental stations of Porabari, Salna, Gazipur, adjacencent to Bangabandu Sheikh Mujibur Rahman Agricultural University, Gazipur and different laborites of Bangabandu Sheikh Mujibur Rahman Agricultural University and Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka, during the boro season, November, 2010 to May, 2014. The results revealed that the plant height, number of total tillers, number of effective tillers, LAI, CGR, NAR and RGR significantly varied among the varieties at different phenological stages as well as the duration of different phenological stages differed significantly among the varieties. From the biological study of yellow rice stem borer (YSB), it was found that the duration of egg to larva, larva to pupa, pupa to adult and total life cycle of YSB were 6. ±0.5 days, 28.2 ± 0.60 days, 8.1± 0.44 days and 42.3±1.25 days respectively. From the coincidence of phenological stages of rice varieties and the stages of life cycle of YSB, it was observed that the adult YSB always appeared maximum and laid eggs at vegetative stage at the 4^{th} week of February and eggs changed into larvae at the same phenological stage, larva changed into pupa at reproductive stage and pupa changed into adult at post reproductive stage of all rice varieties. After harvesting the rice varieties, the newly emerged adult eggs remained in the stubble of paddy fields. This coincidence of two biotic aspects (rice varieties and YSB) continued among the distinct phenological stage of rice and the specific life stage of YSB *(S.incertulas*) in three different rice growing seasons (aus, aman and boro) in Bangladesh throughout the year . Mid-January transplanting time of rice varieties in boro season might be made a temporal favorable coincidence between the each life stages of YSB and the different phenological stages of rice varieties. From the nature of damage, it was found that the infested hills as well as infested tillers were maximum at preflowerng stage and minimum were in active tillering stage in all varieties. Considering the prevalence of appearing of optimum phenological stage of rice and the adult YSB arrival time, percentage of infestation as well as rice yield, the best time for transplanting rice seedling in boro season would be early or late January instead of mid- January. Moreover, the stubble ploughing and flooding the paddy fields after immediate harvesting reduced the percentage of infestation of YSB.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF PLATES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF APPENDICES (Cont'd)

LIST OF APPENDICES (Cont'd)

LIST OF APPENDICES (Cont'd)

CHAPTER 1

INTRODUCTION

Synchronization of coincidences between the life cycle stages of an insect and the phenological stages of its host plant is the best and most environmentally sound natural dynamism. And this is very vital bio-ecological tool for controlling any insect pest (Bashar, 2004; Price, 1988).

The principal importance of the study of relations between insects and their host plants, for the elaboration of crop protection methods, **"The insect-plant relationship symposia"** have brought agricultural entomology out of a cul-de-sac. They have diffused the coevolutionary approach, suggested by G. Fraenkel's article on the **"Raison d'etre of secondary substances in plants"** (Fraenkel, 1959).

Since Ehrlich & Raven (1964) introduced the concept of coevolution, phytophagous insects have been used to demonstrate mechanisms of coadaptaiton between plants and insects. G. Fraenkel (1959) had already stated that the **"Raison d'etre of secondary plant substances"** is an adaptation of plants to the attacks of insects. In most of the studies on this matter, attention is paid to the consumption of the plant tissues by insect larvae. Relationships between the adults of **Bruchus affinis** Frolich (Col. Bruchidae) and **Lathyrus** spp. (Leguminosae) prove that the mechanisms involved can be much more complex (Bashar *et al*., 1987).

Insects' main activities, like longevity, time of growth, fecundity, dispersal, searching capacity,… even when the physical conditions of the habitat have been stabilized (Labeyrie, 1970). It is strange to note that even today many mathematical patterns of population dynamics still use a fixed parameter to characterize fecundity, the intrinsic rate of natural increase (Labeyrie, 1970).

Biochemical studies of the allelochemical substances of the plants have given rise to new possibilities of intervention, bringing along a new generation of insecticides. K. Slama (1969), having discovered that plants can contain chemicals with insect hormone activity. At the same time, resistance factors have been brought out and have helped to lay the basis for selection of resistant cultivars.

In many entomological works, the plants is considered as a homogeneous material. However as early as 1951, in the 9th International Congress of Entomology, V. Dethier underlined that **"the plant is rather an heterogeneous chemical environment"** (Dethier, 1978).

Maintenance and safeguarding of the interactions between plants and animals or among the organisms through functional characterization is the bioresource management (Bashar 2004). "If we want to know animals we should go to plants and if we like to know plants we should go animals (especially insects)" (Feeny 1976). In the era of Feeny, conception on biodiversity and recognition of bioresources were in ambiguous intellectual forays by saying that intellectual forays into the field of 'bioresources and bioresource management' resemble the explorations of an amoeba which extends pseudopodia in many directions simultaneously, follows some, retracts others, seemingly does not know where to it is going, but nevertheless makes progress (Dethier, 1986). But at the present time (since the World Summit of 1992 at Rio de Jenairo), the concept of the above subjects (viz. biodiversity, bioresources, bioresource management) came into a clear cut shape within a frame of definition (Bashar, 2015).

Insect-plant relationship and host-plant selection strategies are based on insect's plant-recognition abilities and adaptations in an ecological condition suitable for both of them (Jermy, 1988).

The insect colonization is a process of establishing insect-plant interaction in open area under the presence of all required necessaries (Plants, insects, water-channel, optimum humidity, temperature, light and other abiotic factors) in a channel which can play as a vital role model for the sustenance of an ecosystem. In this ecosystem, the biotic-biotice interactive mechanism (insect-plant interaction) maintains a synchronization of coincidences between the life stages of insect and the phenological stages of associated plants (Bashar, 2012).

Rice (*Oryza sativa* L.) belonging to the family graminea is the staple food of the people of Bangladesh. It is cultivated under diverse climatic conditions over a wide geographical area. It is normally a crop of a warm humid environment which helps to perpetuate many insect problems. Among the insects associated with rice, the rice borers have been considered to be the most destructive pest throughout Asia. More than 20 species of stem bores have been recorded. However, only the seven species are found in Bangladesh (BRRI, 1996). The available species of borer in Bangladesh are yellow rice stem borer (*Scirpophaga incertulas*), dark headed stem borer (*Chilo polychrysa*), pink stem borer (*Sesamia inference*), pink stripe stem borer (*C. partellus*), goldren stem borer (*C. auricilia*), light stripe stem borer (*C. supressalis*) and white stem borer (*Scirpophaga innota*) belonging to the families pyralidae and noctuidae (Lepidoptera). The most destructive and widely distributed species of the rice borer is *Scirpophaga incertulas* which is commonly known as the yellow rice stem borer (YSB) or paddy borer (Manwan and Vega, 1975)

The insect infests rice crops throughout their growth from the seedling stage to maturity .No matter which continent, ecosystem, or type of crop cultures are there, a field of rice is usually infested by more than one stem borer species. The most prevalent species in Asia is *Scirpophaga incertulas* ,generally monophagous in nature (Khan *et al* .,1991).

More than 175 insect pests infest rice in Bangladesh and about 20 of these have major significance causing yield loss of an economic proportion where the stem borers happen to be the most damaging pests (Alam *et al.*, 1981; Alam *et al.*, 1985;BRRI Ann. Rept., 1984).

Yellow rice stem borer (YSB) is widely distributed in South and South –East Asia (Heinrichs *et al.*, 1985). It causes 5-10% damage to rice crop with about 60% damage in severe outbreaks (Jepson , 1954 ., Catling and Islam, 1982).The yield loss from YSB alone has been reported to be 20-30 % in filed experiments (Alam *et al*., 1985). The YSB has also been reported to be the major pest in deep water rice in Bangladesh (Catling and Islam, 1979). Rice stem borers often show preference for different climates and ecosystems. *S. incertulas* is adapted to the aquatic rice-growing environments of the tropics where it causes the highest annual yield loss among all insect pests. Although it rarely causes damage as extensive as does a brown planthopper epidemic, it is a chronic pest, prevalent in field after field, crop after crop, year after year. *S. incertulas* can also aestivate over a dry season.

S. incertulas is the only stem borer species which is able to survive submergence. Larvae after hatching enter the stem, sealing off the entrance hole and develop in the stem under water. Submerged larvae and pupae of other species would drown, because their entrance holes remain open. Periodic flooding of irrigated rice fields ensures the supremacy of *S. incertulas* in tropical Asia. The pest is more abundant in multiple rice cropping areas (Heinrichs *et al*., 1985). Yellow rice stem borer develops inside the rice stem causing 'dead hearts' and 'white heads'. These symptoms, however, are not visible in all of the damaged stems (Alam *et al*., 1985). Larval feeding reduces stem elongation, plant vigour, tiller number and filled grains (Pathak, 1975).

The rice growing practices in most of the rice producing countries in Asia have changed remarkably during the last two decades. The most significant changes include the use of improved varieties, high rates of nitrogenous and other fertilizers, other intensives practices and growing of more than one crop per year. These changes have increased the prevalence of rice pests including the rice borers. Under such conditions the attack of rice pests can especially be severe, taking a heavy toll of rice production. Therefore, their control becomes in urgent necessity.

Chemical and non-chemical methods have been practiced for stem borer control. A chamber of insecticides have been tested and reported to be effective against stem borers (Pathak, 1967a; Lippold, 1971; Alam *et al*., 1985).

Insecticidal control has severe problems. Cost of insecticides is high, control is generally temporary, residue problem adversely affects the environment and there are other limitations also. Satisfactory alternatives to insecticides, such as use of pheromones, biological control agents and cultural control measures have a weak approach to control the YSB. From the agronomic point of view, it is desirable to determine those factors which influence insect-plant interactions. Knowledge of those factors and an understanding of insect- plant interactions can be invaluable in the development of superior control method with stable levels of insect (Saxena, 1978).

Plant resistance in most cases is of biochemical nature and a number of factors are responsible for resistance by way of antixenosis (non-preference), antibiosis and tolerance to rice stem borers (Maxwell, 1972; Painter, 1951; Panda, 1979; Pathak and Dale, 1983; Pathak, 1969a,b; Pathak, 1977). These factors include morphological and anatomical characters along with biological and physiological factors of rice plant (Chaudhary *et al*., 1984). A highly significant correlation has also been reported to be existing between the number of infested tillers and plant characters which include plant height, leaf size etc. (Pathak *et al*., 1971).

Use of pesticide may not be effective because of covering the YSB (*S. incertulas*) eggs with heavy matrix that prevent insecticide penetration. Biological control is also less applicable due to use organism may become a pest and act slowly. Stem borer control need to be preventive. Indeed, the larvae are very young and hardly visible when they penetrate the stem and it is too late for control when the damage begins. However, no attempts have been made so far on the relationship between phenological stages of boro rice and the stages of life cycle of YSB (*S. incertulas*).

It stands essential for the scientists and researchers in the field of ecosystem assessment to know that the fact of synchronization between the coincidences of two biotic aspects (Plants and insects). In case of our agricultural field, the synchronization of coincidences between life cycle of yellow rice stem borer and phenological stages its host plant (rice) is the established fact in nature. There is a very few works have been carried out till today in the question of the pest management approach by using synchronization of the coincidences. Present attempt has been hypothesized to carry out research in the field of synchronization and coincidences in between the life stages and phenologies of the insects and the plants respectively. Present work has therefore been undertaken to explore a natural tool of control by using a temporal coincidence between the two biotic factors (the rice and the pest insect). This has been envisaged to find out a sustainable control measures of YSB (*S. incertulas*) without harming the environment any way.

1.1 Objectives of the research work

The objectives of the present study are as follows:

- To study the phenological stages of individual seven modern rice varieties in boro season.
- To study the life cycle of yellow rice stem borer (*S. incertulas*).
- To find out the point of coincidences between phenology of the selected rice varieties and life stages of the pest insect (*S. incertulas)*
- To identify the nature of damage done by yellow rice stem borer (*S. incertulas)* at its different stages of life cycle.
- To find out the methods of control of yellow rice stem borer (*S. incertulas)* without harming the environment.

CHAPTER 2

REVIEW OF LITERATURE

The production of any crop mostly depends on its varietal characters. Cultivation of rice is different in their performance even under the same environmental condition. Productivity of rice depends on the type of variety, management and environment. Variety refers to its genetic characteristics which are directed by morphological characters and their responses to environment for yield. Yield is primarily determined by the parameters like effective tiller per unit area, number of spikelet per panicle, percentage of filled grain and grain size. The physiological parameters like leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rates (NAR) are also important to determine the yield potentiality.

Yellow rice stem borer (YSB) is the most important stem borer pest in Bangladesh. Studies on different aspects of the YSB have been done but only a few of them are related to the present study. Research works and information relevant to the present study are reviewed here.

During early 1950's when there was no effective insecticide to control stem borers, treating of the rice straw, screening of rice varieties, hand collection of stem borer moths and eggs, light trapping of moths, and destroying of infested straw or hills were practiced in controlling the pest. Later with the development of powerful synthetic insecticides this pest was controlled using chemicals which had created negative effects on the environment.

2.1 Insect-plant interaction

The insect/plant association, on the other hand, is more realistically a parasite or symbiont host relationship. The plant (the host) in most cases continues to live, and it responds to attack physiologically so that parts not yet consumed may, at least locally, become different from the parts attacked initially. Thus the insect/plant relationship differs from a prey/predator one in that the response to or prevention of attacked by herbivores is chemical and physiological rather than behavioral (in the usual restricted sense of the word). The relationship is based, therefore, on interactions between the sensory system of mobile attacker and the physical and chemical characteristics, together with physiological responses, of a stationary defender (Dethier, 1953).

At the level of habitat the interaction is primarily between the insect and the general environment (of which the plant is a contributing unit but is not a direct interacting participant). Once the plant has come within sensory range, whether this is visual of olfactory, there is a direct insect/plant interaction. The signal indicating the presence of a plant, or a specific plant, now affects locomotory behavior. At this juncture the distribution, density, and community composition of plants may become relevant stimuli. Finally, on the plant itself the insect continues its exploration because, for reasons little understood, no all parts of a plant, or indeed even of a single leaf, are equally acceptable. In short, foraging involves all these locomotory excursions, and the plant itself may be directly involved only in the last two (Dethier , 1978).

There are many biological as well as chemical features that are common to animal and plant cells (especially cytochemical, anatomical, metabolic and biogenetic). However, the nervous and neuroedocrine systems of higher invertebrates and of vertebrate animals have no direct functional counterpart in the plant Kingdom. Thus, one could resasonably argue that the presence of animal hormones in plants might be a fortuitous combination of events having no causal evolutionary grounding. Alternatively, animal hormones belong to the biological most effective compounds ever known. Their presence in plants, just like the presence of certain other pharmacologically actives secondary plant substances, may be thus and outcome of natural selection, which has undoubtedly modulated the interactions between plants and their animal feeders in the course of their convolution. The diffusible tissue factors of plants (Plant hormones) have no direct endocrine functions in the animals, although some of them are often reported as a cause of diverse pharmacological side effects (Slama, 1979).

2.2 Effect of variety

Rafey *et al*. (1989) conducted an experiment with different rice cultivars and reported that 1000-grain weight differed among the cultivars studied. Suprihatno and Sutaryo (1992) evaluated the performances of seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and Way-Seputih as check variety. They concluded that 1R64 was the highest yielding, significantly out yielded the 1R64616H, 1R64610H and 1R62829A/1R54 which in turn out yielding Way-Seputih.

BINA (1993) evaluated the performance of four mutants/varieties viz., IRATOM24, BR14, mutant BINAI3 and mutant BINA19. It was found that they differed significantly on plant height, panicle length, number of non- bearing tillers, and spikelets panicle^{-1}.

Mannan (1996) conducted a field experiment with three varieties, namely, BRIO, BRI1, and BR23 and stated that varieties had significant effect on plant height, total tillers, panicle length, grains per panicle, grain and straw yield. He also reported that BR23 gave the highest grain and straw yields.

Wong *et al*. (1997) worked with high yielding rice cultivars compared popular local cv. Hitomebare and Kijonishiki and found that plant height significantly differed among high yielding varieties and local varieties, low plant height showed high total dry matter (TDM) and extremely large panicle dry weight (DW), which contributed to their large harvest indices.

Julfiquar *et al*. (1998) concluded from several field trials conducted at main station and other regional station of BRRI from 1994 to 1997 during boro season that yields of hybrids from IRRI out yielded the best recommended boro varieties like BRRI dhan28 and BRRI dhan29.

Srivastava and Tripathi (1998) carried out an experiment and showed that increase in grain yield in local check in comparison to hybrid might be attributed to the increase in effective tillers per meter square, fertile grain per panicle, panicle weight and 1000-grain weight.

BRRI (1999) tested three proposed fine aromatic rice varieties viz., Khaskani, Basmati-D and Kataribhog along with to check varieties at four locations in the project area and out reach area. BR5 used as a standard check and Kalizira. Khirton and Khirshapati as local checks. Khaskani gave the highest mean yield whereas, Basmati-D. (2.34 t ha^{-1}) and Kateribhog (2.04) could not exceed of standard check BR5 (2.66 t ha^{-1}) in the project areas. But in the out reach area. The mean yield of Basmati-D (2.32 t ha^{-1}) and Kateribhog (2.32 t ha^{-1}) was similar to 8R5 (2.4 t ha^{-1}).

BRRI (2000) tested the performance of three proposed varieties BR4348-2B-2-2-4, BR4348-2B-2-2-6, BR43-2B-2-2-HR3 along with two standard checks and one local check in 11 locations in transplanted aman. Kataribhog and Khaskani were used as standard check and Chinking, Basmati, Kalizira, Philippine Kateri, Chinnigura. Chiniatop and Bashful as local checks. In Sonagazi and Bogra sadar, the yield performance of the proposed varieties was excellent with more than 4.0 t ha^{-1} yield. Hence, about 30% higher yield was obtained from the proposed varieties over the checks.

Cui-Jing *et al*. (2000) reported from a study of 60 Japanese varieties and 20 high yielding varieties that the plant length showed negative correlation with harvest index but the correlation coefficient between plant length (PL) and harvest index (HI) was not significant. A significant multiple correlation coefficients were obtained between HI and plant height. The ratio of standard partial regression coefficient of PL and HI is 15. It is considered that this plant height is useful index to select varieties with a high harvest index.

Chadra and Das (2000) reported that panicle m^{-2} was significantly and negatively correlated with panicle weight and sterility percentage, while the association of panicle length with panicle weight and 1000-grain weight was found positive and highly significant. Diaz *et al.*, (2000) noted wide variation in panicle length, panicle type, grain $panicIe^{-1}$, panicle weight and secondary branches $panicle^{-1}$ showed the highest level of variation.

Pruneddu and Spanu (2001) conducted an experiment in Sardinia on varietal comparison of rice. They used 18 varieties and classified into groups according to grain properties (round, medium, long A, long B and aromatic) and highest yields were obtained from the long-grained varieties. Alice produced (9.1 t ha^{-1} long A) and Eolo produced (8.4 t ha^{-1} long B).

2.3 Effect on plant characters

2.3.1 Plant height

BINA (1993) evaluated the performance of two varieties IRATOM24 and BRI4. It was found that varieties differ significantly in plant height, number of reproductive tillers, panicle length and unfilled spikelets $panicle^{-1}$. It was also reported that advanced lines had better physiological character like CGR, NAR, and HI and morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

An experiment was conducted on the morphological characters of six Iranian rice cultivars in Rasht, Iran and it was observed that plant height was significantly and negatively correlated with tiller plant^{-1} and positively with days from transplanting to first panicle initiation (Honarneijad, 1995).

High yielding rice cultivars were compared to popular local cultivar Hitomebore and Kijoonishiki and it was reported that plant height significantly differed among high yielding varieties and local varieties. Low plant height showed high total dry matter and extremely large panicle dry weight, which contributed to their large harvest indices (Wong *et al*., 1997).

BINA (1998) conducted an experiment to find out varietal performance of advance line, BINA 8-110-2-6 along with three check varieties, IRATOM24, BRRI dhan26 and BRRI dhan27. The result indicated that BINA 8-110-2-6 appeared similar to BRRI dhan27 in plant height and panicle. Uddin and Azim (1998) reported that plant height showed significant positive correlation with grain yield plant^{-1}.

A field trial was carried out with hybrid Peiai 645/E 32 in Guang Zhou in China during the early season and it was observed that this two-line rice hybrid had a plant height of 115.8 cm with thick and V-shaped leaves of deep green color (Huang *et al*., 1999).

An experiment was carried out with 14 varieties of rice and it was found that the plant height and specific leaf area showed a strong negative and positive significant correlation, respectively. The varieties with a shorter height produced shorter and thinner leaves, which would provide less competition for dry matter and nitrogen between mother stem and tillers and among the tillers (Nuruzzaman *et al*., 2000).

2.3.2 Tillering pattern

Grain yield is positively correlated with tiller number (Yadava *et al*., 1988). Hussain *et al*. (1989) in an experiment with nine cultivars observed that total tillers hill^{-1} differed among the varieties.

In boro season, from an experiment with varieties BRII, BRI3, 8R14 and Pajam, it was observed that total tiller per hill and number of grain per panicle differed significantly among the varieties. The effective tillers per hill of these varieties were 9.4, 8.2, 7.3 and 12.4, respectively (Hossain and Alam, 1991).

Hybrid rice has a strong tillering ability. The quantity and quality of tillers of hybrid rice are markedly superior to those of the conventional varieties. It was found that when transplanted with a single seedling hill^{-1}, the hybrid Shan-Yau 2 produced 15.75 tillers hill^{-1} within 23 days after transplanting, Guang-Xuan 3, a conventional variety, had only 10.12 tiller hill^{-1}. The hybrid Shanyou 2 produced 11 tilllers hill^{-1} after 37 days of transplanting, while the ordinary variety Gui-Zhao 2 had only 8 tillers hill^{-1} (Yuan and Fu, 1995).

A field trail was conducted during boro season and it was found that the hybrid rice Alok 6201 gave maximum number of tillers hill^{-1} and effective tillers over the modem variety IRATOM24 (BINA, 1998), who conducted an experiment with three cultivars (Gulfmont, Rosemont and Trequing) to characterize the contribution of cultivar tillering ability to dry matter accumulation and found that Trequing had the highest tillering ability and partitioned more mass to tillers.

Behera (1998) found that the yield of rice per unit area was dependent mainly on tiller number and average yield panicle^{-1}. Percentage of productive tillers widely varied among the varieties ranging from 42 to 73 % (Yoshida *et al*., 1999). An experiment with three cultivars (Jaya, 1R36 and Pant 4) was conducted to characterize the contribution of cultivar tillering ability and it was found that Pant 4 had the highest tillering ability (Mandel *et al*., 1990).

The relationship between the tillering ability and morphological characters among 14 rice varieties was studied and it was observed that tiller number varied widely among the varieties and the number of tillers plant^{-1} at the maximum tillering stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties, 1R36 followed by Suweon 258 produce the highest maximum tiller number and Dwan produced the lowest maximum tiller number (Nuruzzaman *et al*., 2000).

2.4 Effect of different phenological stages on physiological parameters

2.4.1 Total dry matter and harvest index

There were reports that photosynthesis, dry matter production, grains yield and harvest index varied significantly among cultivars (Arjunan *et al*., 1990). Mia (1993) and Saito *et al*. (1990) observed that the high dry matter production was due to high crop growth rates before heading in the early cultivars and after heading in the medium cultivars.

Fu *et al*. (1991) reported that hybrid rice cv. Yayoa no. 2 had a large sink size, strong tillering ability, high harvesting index, short vegetative growth period, high yield potential and 15% higher yield than cv. Shanyou no.6. Grain yield was positively correlated with dry matter production after heading (Chen *et al*., 1991).

Lim *et al*. (1993) reported from a study of 8 new and 6 old cultivars that the newer varieties were shorter, had a higher percentage of filled spikelets, a higher harvest index and lodging resistant. Longer growth duration in the field produced longer dry matter (Shi and Akita, 1993). Dry mailer production and grain yield was positively and significantly associated with each other and also with harvest index (Reddy *et al*., 1994, Takami, 1990).

In an investigation with some cultivars, the highest dry matter accumulation occurred in the stem until flowering and thereafter, into panicle and grain (Paranhos *et al*., 1995). Dry matter production of culms and leaves were significantly and positively correlated with grain yield and leaf area index. Harvest index was significantly correlated with grain yield, panicle m^{-2} and 1000-grain weight (Chandra and Das, 2000).

2.4.2 Leaf area index

Swaint *et al*. (1986) reported that LAI at flowering stage was associated negatively with photosynthesis but positively with dry matter content and yield. There is a positive correlation between optimum LAI and total dry matter at heading and maximum CGR (Weing and Chen, 1988).

Motomatsu *et al*. (1990) found that the semi dwarf cultivar had higher yield, higher particle weight, large DM accumulation in grains, higher CGR and higher photosynthetic rate alter panicle formation in Japanese cultivars and LAI, leaf culm weight were similar in semi dwarf and Japanese cultivars.

Miah *et al*. (1996) showed that LAI of 7.3 is the maximum that is necessary to give high grain yield. Yield increased with increasing LAI and become maximum at LAI 7. Burondkar *et al*. (1998) studied 15 Japonica and 15 indica varieties grown as first and second crop in the field and found that mid season and late varieties achieved their mean LAI at booting. Some early varieties did not reach maximum LAI until the heading stage both in Japonica and indica in both crops.

Chandra and Das (2000) found that leaf area index (LAI) was significant and positively associated with grain yield. Leaf area index (LAI) showed significantly positive association with dry matter of culms and dry matter of panicles.

2.4.3 Crop growth rate (CGR)

The CGR of BR11 in transplant aman season increased significantly with LAI at around 6 up to 60 DAT and decreased considerably at 70 DAT. The CGR then decreased with out appreciable changes in LAI and solar radiation (BRRI, 1987).

Rahman (1991) reported that there is no optimum LAI for CGR. The CGR reach maximum at a LAI of about 6 for 1R8 and about 4 for peta beyond which it remained the same despite further increase in LAL. The maximum CGR of erect leaved IR8 was greater by 20 g m^{-2} $week^{-1}$ than of droopy leaved peta.

Kabaki *et al*. (1992) studied the characteristics of Japonica, *indica* hybrid rice with reference to dry matter production, yield and tolerance of unfavorable environmental conditions. This resulted in the highest heterosis (140-147%) on the CGR during the 30 DAT. They also reported that CGR of *indica* variety declined markedly after heading.

Miah *et al*. (1996) worked with the 8 rice cultivars of rice and found that crop growth rate (CGR) during the heading to maturity stages, were the lowest among the varietal groups due to the highest decreasing percentage of LAI.

2.4.4 Relative growth rate (RGR)

Haloi and Baldev (1986) found that RGR in chick pea shows higher values at initial stage of crop growth but late sowing markedly enhanced RGR during reproductive stage. Cho *et al.*, (1988) divided the grain filling stage a lag phase up to 5 days after heading, a linear increasing phase (LIP) 5-20 days after heading and a late filling period (LEP) thereafter. Grain weight differences in different panicle regions were greatest during LIP and decreased in LEP.

Kailasam *et al*. (1989) found rapid grain filling between 3 and 13 days after anthesis. Grain production model describing the increase of grain weight as a function of total dry matter production was tested by Kobata and Moriwaki (1990) and found a model of two parameters, grain growth potentials and maximum mobilizable reserves of non-grain plant parts.

Paranhos *et al*. (1997) worked in the plant growth of traditional cultivars. Bulebelle (intermediate) and A (4O9) (Semidwarf) and found that crop growth rate (CGR), relative growth rate (RGR) and leaf area index (LAI) differentiation between the cultivars.

2.4.5 Net assimilation rate (NAR)

Haloi and Baldev (1986) reported that NAR showed higher values at initial stage of crop growth but late sowing markedly enhanced NAR during reproductive phase. Murty *et al*., (1986) found that NAR was associated positively with specific leaf weight (SLW).

Burondkar *et al*. (1998) reported on the NAR, CGR and RGR between 15 days after flowering and found that the yield was positively correlated with NAR, RGR, CGR, TDM and various yield components. Reddy *et al*. (1995) found that varieties differed markedly in LAI, SLW and assimilation rate. Maximum assimilation rate was observed with LAI of 4-5. Assimilation rates decreased with higher LAI due to mutual shading. There was significant positive correlation between assimilation rate and SLW.

2.5 Effect of different phenological stages on panicle characters

Idris and Matin (1990) conducted an experiment with six different rice varieties found that panicle length differed among the varieties and it was greater in 1R20 than indigenous high yielding varieties. Suoez *et al*. (1989) concluded that grain yield was positively and significantly correlated with 1000-grain weight and filled grain panicle^{-1}.

The duration of panicle development was longer in late maturing cultivars than early maturing cultivars and grain yield of the former was greater due to difference in grain number (Sahu and Mohapatra, 1992). Compared to three line hybrid rice, two line inter sub specific hybrid rice have more grains panicle^{-1} and higher proportion of empty unfilled grains (Lu *et al.*, 1992).

The number of spikelets panicle^{-1}, panicle weight and grain yield panicle^{-1} were higher in a particular hill^{-1} with an optimum tiller number and decreased with excessive of large number of tillers (Lee *et al*., 1992).

Yang *et al*. (1997) compared rice hybrids. They found that hybrid between subspecies having longer panicle giving greater yield potential. They also found that there was little difference between the hybrid types in dry matter accumulation up to heading, but after heading the dry weight spikelts^{-1} was higher in the hybrids between sub-species although translocation of assimilates to grains was lower.

The number of panicle m^{-2} was significantly and negatively correlated with panicle weight and sterility percentage, while the association of panicle length with panicle weight and 1000-grain weight was found positive and highly significant (Chandra and Das, 2000). Diaz *et al*. (2000) noted wide variation in panicle length; grain panicle' and panicle weight showed the highest level of variation.

2.6 Effect of different phenological stages on grain characters

Shamsuddin *et al*. (1988) showed that weight of 1000 grains of 9 cultivars ranged from 21.1 g to 31 g. Rafey *et al*. (1989) conducted an experiment with three different rice cultivars and reported that weight of 1000-grains differed among the cultivars studied.

Singh and Gangwer (1989) conducted an experiment with four rice cultivars C14-8, CR-1009, T-5656 and T-6314 and found that grain number panicle^{-1}, 1000-grain weight and biological yield were the highest for C-14-8 among the three varieties.

Yuan and Fu (1995) reported that the leading hybrid rice varieties generally being used commercially in China had about 150 spikelets panicle-1 and 1000- grain weight was about 28 g. The cross between the X ieqinzao A and the restorer line Milyang 45 was made at R in 1983 and it was reported that this indica rice produces large panicles with 110-120 grains panicle-1 and a 1000-grain weight of 28-29g.

An experiment was carried out to study the yield performance of hybrid rice and local check and it was found that increase in grain yield in local check in comparison to hybrid might be attributed to the increased effective tillers m^{-2} fertile grain $panicle^{-1}$,panicle weight and 1000-grain weight (Srivastava and Tripathi, 1998).

2.7 Effect of different phenological stages on grain yield

Five hybrids were compared with the most widely cultivated variety *Oryza* 1. The hybrid 20A /Sudeon 294, yielding 8.2 t ha^{-1}. The other hybrids were not superior to *Oryza*, which yielded 7.5 t ha^{-1}(Munoz and Betancourt, 1992). Suprihatano and Sutaryo (1992) studied the performance of seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and Ways eputih as check varieties, and found that 1R64 gave the highest grain yield.

BINA (1993) evaluated the performance of four varieties/advanced lines along with IRATOM24, BR14. It was found that number of non-bearing tillers. Panicle length, unfilled spikelets $panicle^{-1}$ and grain yield did not differ significantly. Non-significant difference in grain yield proved the agronomic potentiality of the newly developed line BINA 19 to produce comparable yield with IRATOM24 and BR14 which could have been released variety.

The grain and straw yields of seven varieties of rice were evaluated, of which three were native (Maloti, Nizershail and Chandrashail) and four were improved (BR3, BRRI, Pajam & Mala) and it was found that the grain and straw yields were higher in the improved than the native varieties (Chowdhury *et al*., 1995).

Julfiquar *et al*. (1997) carried out an experiment with 40 new hybrid rice and four check hybrids and locally adapted standard check variety and found that seven hybrids were identified as having yield potential and were advanced to further evaluation.

Guowei *et al*. (1998) carried out an experiment with three cultivars (Gulfmont, Rosemont and Tequing) and noted that the higher yield of Tequing constructed with the lower yielding Gulfmont and Rosemont, appears largely to have resulted from its greater tillering ability, higher spikelet density, and longer maturity period.

Julfiquar *et al*. (1998) concluded from seven field trials conducted at main station and other regional station of BRRI from 1994-1997 during boro season that yield of hybrids from IRRI out yielded the best recommended boro varieties BRRI dhan28 and BRRI dhan29.

Rice (*Oryza sativa* L.) genotypes (38) from diverse origin were studied for correlation and path coefficient analysis under cold-stress condition for grain, using 9 characters, grain yield was positively correlatd with 1000-garin weight and negatively with sterility (%) and plant height (Gupta *et al*., 1998). Srivastava and Tripathi (1998) reported that variety influenced the grain yield components significantly. Local checks R320-3000 resulted in the higher grain yield (6.71 t ha^{-1}) that of hybrid 6201 (6.02 t ha^{-1}).

Anwar (1999) conducted an experiment with two hybrid rice and one high yielding variety namely Sonar Bangla-1, Sonar Bangla-2 and BRRI dhan29 and found that Sonar Bangla-1 gave the highest yield (5.39 t ha^{-1}).

2.8 General review of yellow rice stem borer (*Scirpophaga incertulas*)

2.8.1. Nomenclature and composition of rice stem borer species

Yellow rice stem borer, *Scirpophaga incertulas* (Walker) belongs to the family Pyralidae in the Order Lepidoptera (Kapur, 1967) *Scirpophaga incertulas* (Walker) was previously known as *Schoenobius bipunctifer (Walker)* and *Tryporyza incertulas* (Walker) . In 1964 the common name of *Scirpophaga incertulas* was recommended as the yellow rice borer (Barrion and Litsinger, 1981).

Common rice stem borers include 17 Pyralid and 3 Noctuid species (Saito, 1975). The predominant and most destructive species in tropical Asia are *Scirpophaga incertulas* (Walker), *Scirpophaga innotata* (Walker), *Chilo Suppressalis* (Walker*), Chilo polychrysa* (Meyrick) and *Sesamia inferens* Walker (Saito, 1975 and Barr *et al*., 1975).

Seven species of stem borers have been recorded in Bangladesh so far, which *include S. incertulas S. inotata, C. polychrysa, C. auricilia , C. suppressauis, C. partellus* and *S. inferens* (Alam and Catling, 1977).; Alam *et al*. (1972) reported the status of rice stem borer in order of their importance *as S. incertulas, C. polycrysa, S. inferens and C. auricilia.* Alam and Quraishi (1976) mentioned that at Joydevpur, Gazipur as listed in order of abundance, the following three species were present*: T. incertutas, C. polychrysa* and *S. inferens.*

2.8.2 Systematic position of YSB

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Sub-Class: Pterygota

Order: Lepidoptera

Family**:** Pyralidae

Genus: *Scirpophaga*

Species: *Scirpophaga incertulus*

2.8.3 Common name

Dhaner holud majra poka (in Bengali)

Paddy stem borer, or rice stem borer (in English)

2.8.4 Distribution of yellow rice stem borer (*Scirpophaga incertulas*)

S. incertulas is a widely distributed pest and the areas of prevalence lie between $70^0$to 135^0 East Longitude and from10^0 South to about 35^0 North Latitude (Shiraki, 1917). The western limit of its distribution extends to 70^0 East Latitude in Afghanistan and the Southern of its distribution is probably North Australia (Cotterell, 1954). The species is distributed Afghanistan, Bangladesh, Burma, Cambodia, China, Hongkong, India, lndonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, Ryukuis, Sikkim, Sri Lanka, Taiwan, Thyland and Vietnam (Pans Manual No.3,1976). It is the predominant species in Bangladesh, India, Malayshi, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam and parts indonesia (Pagden, 1930; Fernando, 1967; Yunus, 1967; Kulshrestha *et al*., 1970; Soenardi, 1967; Singh and Soenardi, 1973; Chaudhary *et al*., 1976; Khusakul *et al*., 1977).

The stem borers occur every year in each of the three rice crops in Bangladesh and cause losses in every district. Heavier infestations occur in the Southern and Eastern districts, especially in the regions with continuous cropping cultivated. Rice has been reported to be severely affected by stem borers in Barisal, Chittagong, Comilla, Dhaka, Faridpur, Khulna, Noakhali and Mymensingh districts (Alam, 1965; Alam, 1967; Alam *et al*., 1964 and Alam *et al*., 1972).

Rahman *et al*. (2004) reported six species of rice stem borer cause damage to rice and among them the yellow stem borer, dark headed stripped borer and pink borer have major economic significance.

Kapur (1967) reported that in Bangladesh, the most destructive and widely distributed species is yellow rice stem borer (YSB).

2.9. Pest status of the stem borers of rice and their damage

The damage caused by different rice borers is identical. Pathak (1968) described the damage caused by borers. The initial boring and feeding by the larvae in the leaf sheath cause broad longitudinal whitish discolored areas at the feeding sites, but rarely result in wilting and drying of the leaf blades. About a week after hatching, the larvae cease feeding die leaf sheaths and bore into the stem and feed on the inner tissue of the stem walls. Such feeding frequently results in severing of the apical parts of the plant from the point of damage. When this kind of damage occurs during the vegetative phase of the plant the Central leaf whorl does not unfold, turns brownish and dries, while the lower leaves remain green and healthy. This condition is known as ‘dead heart’ and the affected tillers dry without bearing panicles. Dead hearts are sometimes caused by larvae feeding above the primordial and if no further damage occurs the severed portions get pushed out by new growth.

After panicle initiation, severing of the growing plant parts from the base results in drying of panicles. These panicles may not emerge at all. Those that have emerged do not produce grains and remain straight and appear whitish, when they are called ‘white heads’. When the panicles are cut off at the base grain formation is partially completed and shriveled grains are found (Koyama, 1973). The plants can compensate for a low percentage of 'dead hearts' but for every percent of 'white heads' I to 3 percent loss in yield may be expected (Pathak *et al*., 1971). Although stem borer damage becomes visually evident only as 'dead hearts' and 'white heads' significant losses are also caused by larvae that feed within the stem without severing the growing point. It is suspected that such damage results in reduced plant vigor and yield.

A new mode of stem borer (SB) feeding in deep water rice was observed by catling *et al*. (1978). They noted that sometimes the borer enters through the leaf sheath and remains in the lumen of the stem much below the growing point and under water without producing 'dead hearts'.

The extent of crop injury in Bangladesh under various circumstances was 3 to 20 Percent infested tillers (Alam, 1971). Results obtained in different countries indicated that the yield loss due to rice borer infestations ranges from 0.1% to over 80% (Shiraki, 1917.; Tsou, 1947.; McNaughton, 1946.; Van Der Goot, 1948b.; Cotterell, 1954). Israel *et al*. (1965) reported that losses due to rice borer in the earlier stage and heading stage were 1.6% and 26.9% respectively.

Scirpophaga incertulus could attack most of the growing stages of rice plant, beginning with seedling through tillering and up to ear setting, same report also stated by Soehardjan, 1974 and Soehardjan *et al*. (1974).

2.10 Biology and life cycle of yellow rice stem borer (*Scirpophaga incertulas*)

Adults: The adults of *Scirpophaga incertulas* are nocturnal, positively phototropic and strong fliers. The adults show sexual dimorphism. The male is light brown with numerous small brownish dots, five along the sub terminal area and 8-9 near the tip of the fore wing. The female is yellow, and there is a very distinct black spot in the Centre of each fore wing. The hind wings are pale straw colored. The body length is 13-16mm and the wing span is 22-30 mm. It lives for 4-5 days (Pans Manual No. 3, 1976).

The moths usually emerge between 7 to 9 p.m. (Hassanein, 1959) and during day time they remain in hiding in rice fields (Koyama, 1955). The female moths mate only once (Padilla, 1966; Rothschild, 1971) soon after emergence. Mating generally occurs between 7 to 9 p.m. and the ovipositor occurs between 6 to 10p.m. The female moth deposits only one egg mass per night while ovipositor may occur up to 5 nights from emergence. Ovipositor duration lasts for 10 to 35 minutes. Alam *et al*. (1985) reported that adult moths live 5-9 days and are most active 1-3 hours after sun set.

Eggs: The eggs of *S. incertulas* are laid in mass on the lower surface of the leaves (Jepson, 1954) near the tip of the leaf blade. They are covered with pale orange brown hairs from the anal tufts of the female moths (Banerjee and Pramanik, 1967 and Pathak, I968). In general, the moths lay more eggs on the upper surface than on under surface of the leaf when the plants' are young (Kiritani and lwao, 1967). An egg mass contain 50 to 80 eggs and a single female is capable of laying 100 to 200 eggs. Incubation period varies from 6 to 7 days in the active season (March-November) according to Catling and Alam (1977). The optimum Conditions for hatching are 90-100 percent relative humidity and 24- 29^{0}C. Light at 10 foot candles accelerated the hatching period (Areekul and Chamchanya, 1973).

Larvae: The yellow borer larva is 25 mm in length and 3 mm in width. When full grown (after 40 days), it has an orange head capsule and a rather small head relative to the width of the body (Pans Manual No. 3., 1976). Puttarudriah (1945) observed that full grown larvae in the field collections were found to measure up to 20 mm long and 2.5 mm broad, colour being yellowish White and head orange yellow. The hatching larvae are negatively geotropic and crawl upwards towards the tip of the plants where they stay only for short periods. Some suspend themselves with a silken thread which they spin, and swing with the wind to land on other plants (Soenardi, 1967). Those which fall on water can swim because of an air layer around their body (McNaughton, 1946). Most of those remaining on the tip descend towards the base and crawl in between the leaf sheath and stem. Then they congregate and enter the leaf sheath through a common hole bored by one of them (Koyama, 1956), feed in the leaf sheath tissues for about a week (Pathak, 1968) after which they bore into the stem mostly through the nodal regions (Djamin and Pathak, 1 967).

Scirpophaga incertulas larvae rarely feed gregariously. The larvae seldom enter seedling but, if they do, boring takes longer and there is low survival. During the vegetative phase of the plant the larvae, generally enter the basal parts, usually 5 to 10 cm above the water level. But on older plants they bore through the upper nodes and feed their way through the nodal septa towards the base (Banerjee and Prarnanik, 1967). On a crop at heading stage, boring usually occurs at the peduncle node, forming white heads even with slight feeding (Pathak, 1969 a, b). At this stage the larvae cause maximum damage. The YSB larvae from second instars onwards migrate by using body leaf wrapping. The larvae require a minimum of 16^0C as the lower threshold temperature.

The larvae usually undergo 4 to 7 larval instars stages. When reared at 23 to 29^0C most larae undergo five instars but at 29 to 35^0C there are four only (lin *et al*., 1959). The number of moults is reduced in larvae feeding on maturing plants compared to that in the tillering phase, but increase where available host plants are limited and in the hibernating larvae (Kiritani and lwao, 1967).Under favorable conditions larval period ranges from 22 to 43 days (Van Der Goot, l948a, Otanes and Sison, 1952 and Moiz, 1967). The average larval period is 36.5 days and during June- September it varies from 17 to 27 days (Alam *et al*., 1985).

Pupae: Pupae are yellowish white with a tinge of green and measure about 16 mm long. The pupal stage which takes place inside the stem often below the, soil surface, lasts for 8 days (Pans Manual No. 3, 1976). Puttarudriah (1945) observed that pupae were found to measures 12.00 mm long and 3.00 mm broad, being pale coloured at first, gradually tuning dark brown in the thoracic and cephalic area ventrally. The abdominal region including a few segments remained pale. The duration of the pupal stage was 10-12 days.

The full grown larvae before pupating cut exit holes in the internodes through which the emerging moths escape. Usually the external opening of these exit holes is spun with fine web and may not be easily visible before the moths have escaped. The pupae are covered with whitish silken cocoons. The anterior extremity of these cocoons is tubular and attached to the exit boles; often one or two horizontal septa webbed by the larvae in this tubular to make the cocoons waterproof. The full-grown larvae have a tendency to feeding the basal parts of the plants. In a harvested crop almost all the larvae are usually left in the stubbles. The overwintering larvae pupate in the stubbles (Pathak, 1969a). The threshold temperatures for pupal development are 15 to 16°C (Lin *et al*., 1959).

2.11 Ecology of yellow rice stem borer (*Scirpophaga incertulas*)

2.11.1 Population ecology

According to Pathak (1968), the rice stem borers are poly-voltine and the number of generations in a year are dependent on environmental factors, primarily temperature and crop availability.

2.11.2 Seasonal occurrence

Manickavasagar and Miyashita (1959) reported that the number of generation of *S. Incertulas* differs from one country to another, tending to decrease in the northern limit of its distribution. In fact, the number of generations of the species varies from 2 to 8 depending on the temperature and the rice growing period of the country where it exists.

In Bangladesh it has five generations. Alam (1964); Alam (1965) and Alam *el al*. (1972) reported that the first generation was on Boro, second and third on Aus, fourth on Aus and Aman and the fifth on Aman crop including stubble. Catling and Alam (1977) in their review mentioned that among the 7 generations of the species in Bangladesh, the first one emerged in the month of February and the seventh brood entered diapauses in mid-November.

2.11.3 Stubble and abundance

Prakasa Rao *et al*. (1971) observed that 43.3 percent of stubbles were infested with rice stem borers and 32.8 percent hills of the infested stubbles contained immature stages of borers. The composition of *S. incertulas, Chilo spp.* and *S. inference* were 74%, 12.5% and 13.5% respectively. Catling and Alam (1977) in their review reported that 90 percent of the population hibernated in the larval stage in rice stubbles from November to February (or March) and the rest hibernated as pupae till the or second week of February depending on the prevailing temperature. Zafar (1983) observed the hibernation of *S. incertulas* in the stubble of harvested fields and his studies indicated that destroying of rice stubble after harvest was essential for minimizing YSB incidence.

2.11.4 Weather conditions and abundance

The percentage incidence of ‘dead hearts’ and ‘white heads’ were both correlated negatively with rainfall and minimum temperature and positively with maximum temperature (Prakasa

Rao, 1983). The percentage of 'white heads' and relative humidity were negatively correlated (Abraham *et al*., 1972). Padi and Saha (2004) found that the YSB fluctuate duo to the weather parameters.

2.11.5 Natural enemies and abundance

In Asia 100 species of natural enemies were recorded from rice stem borers (Yasumatsu, 1972). High population of natural enemies of egg masses, larvae and pupae during the months of March and April brings about a decline in the stem borer population (Prakasa Rao *et at*., 1971). Egg parasitism is considered as the chief biotic factor in regulating population (Rao, 1964., Prakasa Rao, 1972). Rothschild (1971) found that mortality egg and pupal stages exceeded 98 percent in most seasons. This was attributed to the s predators and egg parasites. Larval parasitism rarely exceeded 2 percent but pupal parasitism was somewhat higher. Catling and Alam (1977) listed as many as 26 species of natural enemies (parasites) of the immature stages of rice stem borers in Bangladesh.

Three egg parasites are important in limiting the populations of yellow stem borer in Bangladesh (Catling, 1979). In winter and early summer (Boro and Aus crops) 12 to 25 present of the eggs were parasitized by *Teicnonius rowani* Gahan and *Trichogranmia japonicum* Ashmead. In the Monsoon season (Aman crop) the complex is joined by T*etrastichus schoenobii* Ferricre, and 71 to 88 percent of the egg masses including over 50 percent of the eggs were parasitized with highest rates of parasitism (65%) occurring in September to October.

Among the predators, the ants (*Monomorium latinoda* Meyer and *Tetranorium simillimum* Sm and birds (Crows, Mynhas and Drongos) have been reported to be important.

2.12 Population estimation of yellow rice stem borer (*Scirpophaga incertulas*)

Rothschild (1971) studied the biology and ecology of rice borers in Sarawak, Malaysia the sampled and estimated eggs, larvae, pupae and adults during the experiment.

2.12.1 Estimation of egg number

As *Scirpopha*ga egg masses were easily overlooked and were rarely found, estimation the impossible by field counts. Number of eggs laid in the crop was calculated from numbers females emerging and from their mean fecundity (Rothschild, 1971).

2.12.2 Estimation of larvae and pupae

Numbers of larvae and pupae of rice borers were estimated by dissecting each tiller of sampled 200 hills. Early instars of different species could not be identified to species, and it was guessed that they were in the same proportions as in the later: stages (Rothschild, 1971).

2.12.3 Estimation of adults

Rothschild (1971) mentioned that emergence traps (Southwood. 1966) set over individual hllls and sweeping with a net or power suction sampler (D-vac model) were not practicable. Tentative estimates were derived from counts of healthy pupae and pupal cases by Rothschild (1971). Light traps are sometimes used to estimate the occurrence and abundance of rice borers. High peaks in the catches indicate the presence of larvae of insects in the field. Rothschild (1971) during his studies at Sarawak used light trap for finding out relation between adult numbers and crop infestations. Fukaya and Nakatsuka (1956) reported a high positive correlation between light trap catches and percentage of infested tillers. Light trap can be used to study the pattern of stem borer occurrence and to find the peak periods of abundance (Saroja and Raju, 1981).

2.13 Off-season activities of yellow rice stem borer (*Scirpophaga incertulas*)

Fukaya (1967) remarked that high adaptation to environmental condition during winter was observed in case of stem borers distributed over the temperate zone. *S. incertulas* larvae began to move down the base of the rice plant in autumn, and remained in stubble in winter. On the other hand, diapause, the physiological adaptation, which was gained throughout the period, prior to hibernation was typical pase of adaptation to severe climate as well as to starvation during winter.

During off-season *S. incerrulas* larvae can only survive by breeding in ratton or by entering a resting stage. It occurs in stubbles with somewhat yellow coloured shrunken body remaining fat. Numbers of *Scirpophaga* larvae in ratton rice plants were relatively high with estimates of up to 140 larvae/200 plants, while stubble counts varied between 12 and 19 larvae plants (Rothschild, 1971).

2.14 Host range of yellow rice stem borer (*Scirpophaga incertulas*)

Scirpophaga incertulas is strictly monophagous, feeding solely on the rice plant (Torri, 1971, Koehler, 1971). There were numerous alternative hosts of this species like wild, weeds (Banerjee and pramanik 1967.; Torri, 197l.; Arvind, 1987) and wild rice (Zaheruddin and Prakasa Rao, 1983) in india.

2.15 Rearing of the yellow rice stem borer (*Scirpophaga incertulas*)

As previous workers made unsatisfactory mass rearing attempts by placing larvae on 40 to 45 days old rice plants or cut stem pieces of flowering plants, or feeding them artificial diet. Medrano and Heinrichs (1985) developed a simple mass rearing technique using healthy booting stage rice plants. IR 62 was used as a food plant because it was early maturing high tillering and YSB susceptible, but was resistant to several other insect and diseases that infest a greenhouse culture.

Six hills of 14 days old IR 62 seedlings were transplanted weekly in a 34 x 25 x 11 cm plastic basin containing rice soil. At booting stage, about 63 days after sowing, tillers with leaf sheaths were infested with 2 larvae/tiller. A 2.5 cm slit was cut along the mid of the bulging leaf sheath. The incision was opened by spreading the cut edges to about 1 cm, ‘which exposed a small section of the growing panicle. The slit was held open and YSB larvae were placed on the exposed panicle with a camel hair brush. When the edges of the slit closed, the insects were trapped inside the boot; Smoking was strictly prohibited during this procedure because newly hatched YSB larvae were highly sensitive to tobacco smoke.

Infested plants were placed in a 1.5 x 5.5 xO.l5 m water pan tray inside a large screen the water provided moisture for the plants and prevented ants from feeding on the insects. When the larvae pupated 25-30 days after infestation (DAI) the plants were cut to 15 cm. height and transferred to an adult emergence cage in another water pan tray. When adults 31-40 DAl, they were transferred to an ovipositor cage containing 40 to 45 clays old potted TN1 plants. The YSB laid eggs on TN1 1-2 days after emergence.

Potted plants with egg masses were collected daily (32-41 DAI) and placed in a water pan tray. To maintain the culture, the leaves of the TNI plants with egg masses laid in 36 DAI were cut into small pieces 4 days after oviposition. The leaf pieces were placed in test tubes or ball jars with moist cotton at the bottom. The eggs hatched in 42 DAI. Larvae were then placed on booting plants and the cycle was repeated. To provide larvae for experiments, cut leaves with egg masses in 32-35 DAI and 37-41 DAI were placed in test tubes. The hatching larvae were varietal screening for resistance or for basic studies of resistance mechanisms.

2.15.1 Ovipositor cage

In the past ovipositor cages were used to collect stem borer egg masses at IRRI when many of the egg masses were laid on cage surfaces other than the one designated for ovipositor. An improved ovipositor cage for rice stern borers was then developed by Davis and Vega (1982) at IRRI to force female moths to ovipositor on the desired substrate. The cage consisted of a wooden frame 45 cm wide x 52 cm high covered with nylon screen. The cage bottom was made of wood. Common air conditioner foam rubber filter was stapled on intercage wood surfaces. The preferred ovipositor substrate of wax paper strips (15.24 cm wide x 60.96 cm long) were held in place vertically by slipping the paper through wooden slots at the top and bottom of the cage securing with tape. Slots were partitioned 12.5 cm apart .*Scirpophaga incertulas* moths collected around light sources laid 80% of their egg masses on the wax paper

2.16 Sampling Methods for yellow rice stem borer (*Scirpophaga incertulas*)

Nishida and Torri (1970) suggested rice stem borer sampling methods. There are several methods for determining the percentage of infested tillers. Any of the following formulae can be used depending on the degrees of accuracy, desire or time given for sampling:

a) $$\frac{\text{Dead hearts or white heads}}{\text{Total number of tiller observed}} \times 100\% \text{ DH or WH (Pathak, 1970)}$$

b). Onates formula: X= P X-nz 100

Where,

$$P = \frac{\text{No. of affected hills}}{\text{No. of hills in the plot}}$$

$$X - nz = \frac{\text{No. of dead hearts/ infested tillers}}{\text{No. of tillers in the affected hills}}$$

X= Percentage of dead hearts or white heads

c) Modified formula: $\dfrac{AxC}{B+C}$

Where,

A= Number of infested hills,

B= Number of uninfected tillers,

and C= Number of infested tillers(Onate, 1965)

d) Gomez's formula:

$$P = \frac{I}{Nx+(n-x)\,Y} \times 100$$

Where,

P= Percentage of DH or WH

I= the total number of infested tiller from all infested hill (DH or WH)

X= the average number of tillers per hill from all infested hills

Y= the average number of tillers per hill from 10 uninfested hills.

N= the total number of hills (infested and uninfested) in a plot (Gomez, 1972),

e) Dead heart index (Chaudhary *et al*., 1984)

$$= \frac{\text{\% dead hearts in the test entry}}{\text{\%dead hearts in the susceptible creck}} \times 100$$

The dead heart index has a corresponding rating on a 0-9 scale (IRRI, 1980) which indicates the level of resistance.

Stander evaluation system for scoring stems boere resistance (IRRI, 1980)

Dead heart (%)	White head (%)	Scale	Level of resistance
0	0	0	Highly resistant
1-20	1-10	1	Resistant
21-40	11-25	3	Moderately registrant
41-60	26-40	5	Moderately susceptible
61-80	41-60	7	Susceptible
81-above	61-above	9	Highly susceptible

Similarly scoring is done for white heads at the soft dough and mature grain stages. The test is considered valid when 'white heads' in the susceptible check average at least 10%. Data on percentage of 'white heads' can be translated into a 0-9 scale.

2.17 Effect of plant age and time of transplanting on the incidence of yellow rice stem borer (*Scirpophaga incertulas*)

Kamran and Raros (1968) worked on seasonal fluctuation and abundance of various borers on Luzon Island of the Philippines both during the wet and dry seasons. In the wet the samples taken 30 days after transplanting showed fairly high infestation. Samples 60 days after transplanting showed a slight decrease in the population. But in the rest les (taken 90, 120, 150 and 180 days after transplanting) the population gradually increased. During the dry season borer population was lower in comparison to wet season. Saha and Saharia (1970) reported that the intensity of rice borer infestations decreased with delayed transplanting in Assam (India). Transplanting time also influenced the yield of rice (Naher, 1995).

Prakasa Rao, *et al*. (1971) reported that two distinct peak periods of incidence of rice orders occurred at Cuttack. First one when the wet season crop (Kharif) was at the heading stage and the dry season crop (Rabi) was in the nursery stage and the second one at the heading slage in the Rabi crop. Crops planted in the month of September remained almost free of rice borers hut crops planted in the month of October suffered considerable damage the heading stage. Crops planted from mid-December to late January suffered low borer infestation hut crops transplanted during February or there after suffered from high infestation both at tillering and beading stages.

Abraham *et al*. (1972) conducted research at the IRRI and found that maximum borer infestation was in the crops planted during the period from the first fortnight of October to the first fortnight of January and the lowest pest infestation was observed in the crops planted during the period from the first fortnight of June to the first fortnight of October. Soehardjan *et al*. (1974) reported that in general, there was an increase in the level of infestation with the increase of the age of the rice plants. In Java it was found that the highest of stem borer infestation was always found between the period of 3 months after Planting and the date of flowering. Hussain *et al*. (1989) found that percentage of infested tillers during white head formation was in general, higher than percentage of infested tillers formation in Boro and Aug seasons. During Aman season the trend was not consistent. He considered that rice plant could be more susceptible to rice borer attacks just before panicle formation. It was also observed that 'dead hearts' were generally more 'white heads' during Boro and Aman but lower in Aus. All these observations were statistically insignificant.

Manwan and Vega (1975) observed differences in the resistance of the rice plant at differe11 growth stages of the rice plant. During the later stages of the plant growth the borer infestation and the number of surviving larvae decreased. Earlier infestation (30 days after transplantation) caused higher damage than later (60 and 90 days after transplanting) infestation. Pathak (1967b) indicated that the borer population was affected by the age of the plant, variety and soil fertility level. Pathak (1968) observed that more eggs were received by rice plants in the vegetative and early heading stages than in the stages nearing maturity. It appeared that availability of host plants at the attractive stages for long period encouraged the pest population increase. Pathak (1968a) in his review remarked that in areas having distinct generations the borers were more destructive to the late planted crop or second crop where double crop was practiced.

Mallik and Behera (1965) found that attack of *T. incertulas* was maximum on 90 days old rice plant. Prakasa Rao (1972) noted that active tillering stage followed by that at just flowering was more preferred by *T. incertulas* for oviposition. The damage to summer crop was serious, autumn crop comparatively low but in the winter crop it was wide spread and moderate (Banerjee and Pramanik, 1967).

Catling and Alam (1977) reported that the early boro crop was relatively unaffected, but late. Planted. Fields or long duration varieties were often attacked considerably at booting and flowering stages. Aus and Aman crops are attacked at tillering as well as flowering stages.

Fewer larvae survived and emerged on younger rice plants. Survival increased with plant age up to 34 and 40 days after sowing (DAS), then declined progressively on plants aged 46 and 52 DAS. Fewer dead hearts were observed in younger plants than in plants at 34, 40 and 46 DAS. Dead heart count declined sharply at 52 DAS. Larvae were heaviest on plants at 40 DAS. They weighed less on plants at 34, 46 and 52 DAS (Viajante and Saxena, 1988).

IRRI (1987) reported that fewer 'dead hearts' were observed in younger plants than in plants at 34, 40 and 46 DAS. Dead heart count declined sharply at 52 DAS. Israel *et al*. (1965) reported that losses due to rice borer in the earlier stage and heading stage were 21.6% and 26.9% respectively. Chandramohan and Chelliah (1983) screened 170 rice varieties against YSB at Coimbatore, India and found that varieties W 1263 and JR 136-41-4 were moderately resistant at the seedling stage and resistant at vegetative and reproductive stage. Co18, 1R136-39-39 and Sornavazhai were moderately resistant at all stages.

2.18 Plant morphological characters influencing the infestation rate of yellow rice stem borer (*Scirpophaga incertulas*)

Pathak (1967b) indicated that the borer population was affected by the age of the plant, .variety and soil fertility level. Pathak (1969b) and Pathak *et al*. (1971) observed a highly significant correlation between the number of infested tillers and morphological plant characters. Early maturing varieties develop few white heads (Lippold and Karim, 1970). IRRI (1974) reported that the resistant plants were comparatively less damaged than the susceptible hosts.

Patanakamjorn and Pathak (1967) reported that resistant varieties possessed tight leaf sheaths which totally covered the internodes, whereas susceptible varieties had loose leaf sheath the partially covered them. Differences in varietal resistance were explained by the ease at which migrating larvae reached and fed on the inner part of the leaf sheath before boring into the stem. It was observed that 95% of the larvae migrated to between the sheath and the stem within 48 hours after hatching and established more easily on loose sheathed varieties. Padhi and Prakasa Rao (1978) suggested that the resistance of wild rice species was due to antibiosis and slender and tough stems. Varieties with bigger stem were more susceptible (Fukaya, 1947; Jodon and Ingram, 1948; Koshiary *et al* 1957; Pawar *et al*. 1959 and Ghosh, 1960). Chamblish (1920) and Douglas and Ingram (1942) observed that large stemmed varieties were more often damaged than small stemmed varieties.

Plants with wider and longer leaves, a large number of tillers per hill, higher diameter of stalk and pith and tall stature appeared more susceptible to stern borers (Van Der Goot, 1925 Okamoto and Abe, 1958; IRRI, 1964 and I65; Israel, 1967).

2.19 Oviposition preference of yellow rice stem borer (*Scirpophaga incertulas*) on different rice varieties

Wada (1942) obtained a positive correlation between the number of egg masses and growth of stems and leaves and also with length and breadth of leaves. According to Seko and Kato (1950a) varieties exuding larger quantity of dew drops on the leaf blade edges received more egg masses. The dew drops contained small quantity of ammonia which an attracted the stem borer moth. Matsuo (1952) reported the variation in number of egg masses laid by the rice stem borer on different varieties to their nitrogen absorption capacity. A stem attractant, oryzanone, was recovered from a susceptible rice plant by Munakata *et al*. 1959). Oryzanone attracts ovipositing moths by its odour.

It has been reported that *Scirpophaga incertulas* moths preferred laying more eggs on the dorsal side, followed by ventral side and leaf sheath under caged condition (Kojima, *et al*. 1955), Kalode and Israel (1970), Prakasa Rao (1972) and Padhi and Chatterji (1984). Prakasa Rao (1972) also reported that any portion of leaf (basal, middle and apical) suitable for Oviposition by the moths. The egg laying of the yellow stem borer moth was seen maximum in early tillering stage of crop (Prakasa Rao, 1972 ; Padhi and chatterji (1984) observed that susceptible variety received the highest number of egg masses and the egg masses covered more area. The middle portions of rice leaf t prefer for egg laying by YSB moths than the basal and apical portions. Perhaps, due to width of the leaf and size of the abdomen of the moth.

Lukefahr *et al*. (1965) reported that borers preferred glabrous surface of the leaf to the hairy ones. The susceptible variety 'Jaya' received the highest number of egg masses. The susceptibility of 'Jaya' might be due to more water vapour or free moisture or odour which stimulated oviposition by the moths (Panda *et al*., 1975). Pathak (1967b, 1969b) and Pathak *et al*. (1971) demonstrated that a number of factors were responsible for resistance by way of non-preference, antibiosis and tolerance. They demonstrated that egg laid by the striped borer on the various growth stages of the susceptible variety 'Rexoro' was 2 to 8 times higher than that laid on the resistant variety 'Taitung 16' and 'TKM6'. The moths prefer younger plants for oviposition to plants nearing maturity.

Patanakamjorn and Pathak (1967) reported several factors associated with preference or non-preference for egg laying. Plant height, stem diameter and length and width of flag leaf were positively correlated with numbers of egg laid. Tall varieties might have been more attractive to ovipositing moths, in a separate experiment it was observed that the length and Width of flag leaf blade had a high positive correlation with number of egg masses laid (0.743 and 0.924 respectively). Although there was a negative correlation between hairiness of leaf blade and the numbers of egg masses laid, further studies indicated that some additional factors other than hairs were responsible for non-preference (Pathak, 1971; Pathak *et al*., 1971).

It has been reported that difference in the number of eggs laid on different rice varieties were significant, although correlation with difference in plant height or number of tillers per hill or number of leaves per tiller was not shown (IRRI, 1974). Reports are also available that the YSB moths lay eggs on iron poles, wooden frames and cloth surfaces of that the resistant varieties in the Cages 9 (Manwan and Vega,1975; Pathak ,1977 ; Padhi and Chatterji 1984. Manwan and Vega (1975) observed general, were less preferred by moths for oviposition. Nitrogenous fertilizer has been reported to increase the number of egg mass deposition.

Islam (1991) reported that the correlations between egg masses and plant height and tiller density were positive and significant. 'Taller and denser canopies were more preferred for egg deposition. BR 41 12B-6 was least preferred, probably because it had the shortest Plants and produced fewer tillers. Leaf blade width and foliage colour had no apparent on egg deposition. Islam and Catling (1991) studied the biology and behavior of the rice yellow stem borer in the deep water rice environment. They observed that female moths preferred the distal half of the second leaf from the top for egg deposition.

2.20 Role of antibiosis in rice against yellow rice stem borer (*Scirpophaga incertulas*)

Tsutsui *et al., (*1957) suspected that the components of rice plants at the early ear head formation stage were detrimental to larval growth and that oxalic acid is a substance nutritionally injurious to the larvae. The presence of antibiosis in some resistant varieties as in feeding demonstrated experiments was expressed in low survival and low growth rate of early instars larvae of the rice borer suffered from higher mortality on resistant varieties resulting in reduced population in subsequent generations (Pathak, 1964).

Stem borer larvae (*Chiio suppressalis*) had significantly lower survival on resistant than on Susceptible varieties .The differences were not pronounced during the first 5 days hatching, but at 20 days,larvalsurvival was 70 to 80 percent on susceptible varieties compared to 40 to 50 percent on resistant varieties. Pupation reached 69% in 30 days after Infestation. On resistant varieties only 20% had pupated 40 days after infestation. A significantly lower survival of larvae of *S. incerrulas* and *T innotata* on resistant varieties rice on susceptible ones was observed (IRRI, 1964). The larvae which fed on resistant varieties suffered high mortality and were smaller than those that were fed on susceptible varieties (IRRI, 1972).

2.21 Controls of yellow rice stem borer (*Scirpophaga incertulas*)

2.21.1 Bio-control

Biological control is one of the major components of IPM. In nature many organisms are surviving by feeding on other insects. Predators, parasites and disease of pest are available in abundance, which have been identified to maintain natural balances to reduce pest incidence. Use of these natural occurring living organisms to check pest population is one of the safest methods of pest management (Razvi, 1991).

The Asiatic corn borer, *Ostiniafurnacalis*, is the most important insect pest of corn in Taiwan. Yield loss can be as high as of many other major insect pests. Other than the aboriginal species, the exotic wasp *Trichogramma embryophagum* was introduced to fortify the biological control of Asiatic corn borer in Taiwan. Kumar *et al*. (2007) reported that bio-intensive pest management is very useful to control the yellow rice stem borer. 30% of the total production. Application of *Trichogramma* egg parasitoids in Taiwan has been very successful since the mid-1980s. The *Trichogramma* wasps are also important egg parasitoids

In combination with the egg parasitoid, *Bacillus thuringiensis* baits have also been used in the field to enhance the control effect. The *Bacillus thuringiensis* baits coated with attractant to Asiatic corn borer not only prolong the duration of pathogenicity under sunlight, but also stimulate the feeding of the borers and therefore greatly improve the control effect. Use of predators to control spider mites and bulb mites, Fortyseven species of native predators has been recorded as natural enemies of spider mites. Tripathy and Kanungo (2008); Atwal and Dhaliwal (2005) reported that integrated pest management is very effective for controlling the YSB.

This species, along with three exotic species, *A. californicus*, *A.fallacis and Phytoseiulus persimilis*, have been effectively used for the biological control of spider mites on pear, mulberry, tea, strawberry and papaya in Taiwan. Dani and Jena (2008), Singh *et al*. (2006); Verma *et al*. (2004) and Verma *et al*. (2002) reported that pheromone trap reduced the infestation of YSB.

Predators of bulb mites include the *Cecidomyid flt* and predaceous mites. Among them, *Hypoaspisa culeifer* was the most abundant species commonly found in the field. *H. aculeifer*, with the ability to suppress the population growth of bulb mites, was proven to be an effective natural enemy (Seko and kato 1950).

Entomologist in Taiwan developed a machine to produce encapsulated artificial diets for the green lacewing. The low cost and labor-saving rearing system enables the production of large quantities of green lacewing within a short period of time. Marwat *et al*. (1985), Gupta *et al*. (2002), Khan and Baloch (1967), Munakata and Okamoto (1967), Panda *et al*. (1973) and Oliver *et al*. (1975) reported that the resistant variety reduced the infestation of borer species. Akinsola (1973) and Nozato (1982a, 1982b) observed that the larvae of YSB became comparative smaller in resistant variety. Nakano *et al*. (1961) found that the plant containing more silicon became more resistant to the stem borers. Padhi and Chatterji (1986) observed that there is a positive correlation between nitrogen in rice varieties and the infestation of stem borers.

2.21.2 Chemical control

Many organophosphates insecticides were identified and doses were fixed for the management of important insect pests. About 76 insecticides in different formulations were screened against different insect pests and many of them were recommended for use. The emphasis of a pesticide umbrella to check insect incidence was dropped as the new information generated on effective dosages, method and time of application led to the development of the need-based chemical application approach which aid in minimizing economic loss caused by pest damage without resulting environmental pollution. A large number of granular formulations of insecticides were tested in soil for the management of stem borer, gall midge, leaf and plant hoppers. Lindane, diazinon, dursban, sevidol, endrin and carbofuran were effective against stem borers. Cytrolane, phorate and dursban were effective in reducing gall midge incidence. Both groups of insecticides were also effective against leaf and planthoppers.

Two applications of any effective insecticide, first between 20 and 25 days and the second between 55 and 60 days after transplanting were effective in checking borer damage while applications at 10 and 25 days after planting were critical for the gall midge. During eighties and nineties, newer insecticides like Eviseet, isofenphos, endosulfan and ethioprop as granules at 1 kg a.i./ha were found effective against stem borers in the early stage of the crop. Ficam, monocrotophos or quinalphos as foliar sprays at 0.5 kg a.i./ha were effective against stem borers at heading stage of the crop. Application of oncol and ethioprop at 1 kg a.i./ha was promising against the gall midge. Phorate and BPMC granules were effective against the white-backed planthopper. monocrotophos or at 0.5 kg a.i./ha as spray were effective against brown plant hopper. Sub-soil application of mephospholan, isofenphos or carbofuran granules at 1 kg a.i./ha was effective than broadcasting of the same.

Dry seed or sprouted seed treatment with 0.02% carbofuran, carbosulfan, chlorpyriphos or isofenphos provided effective control ofboth stem borers and gall midge for 30 days. Triphenyltin hydroxide, an organotin compound was found to inhibit the feeding activity of first instar larva of yellow rice stem borer to the extent of 25-55% when used at 0.02 to 0.1% concentration over control (Ishii *et al*., 1962).

Control of *Scirpophaga incertulas* in rice was attempted by mating disruption using the natural ratio of pheromone components, a 1:3 blend of (Z)-9- and (Z)-11-hexadecenal, in replicated trials by Cork *et al*. (1998) at three locations in Andhra Pradesh, India, during 1994 and 1995 dry seasons. The pheromone was formulated in Selibate and applied by hand at a rate of 40 g a.i./ha. In Medehal and Nellore, pheromone-mediated communication was reduced by at least 94% for the first 50 and 64 days after application, respectively, as measured by pheromone trap catch suppression. Compared with adjacent farmers' practice plots, subsequent dead heart and white head damage were reduced by 74 and 63% and 83% and 40% in Medchal and Nellore, respectively. In Medehal, average rice yields were increased compared to the farmers' practice plots, 4108 and 3835 kg/ha respectively, but in Nellore, they were the same as those obtained in the farmers' practice piots, 6400 and 6733 kg/ha. In Warangal the level ol communication disruption over the first 70 nights after pheromone application was less than obtained in either Medchal or Nellore and averaged between 50 and 87%. The maximum dead heart and white head damage recorded in the pheromone-treated plots in Warangal was 2.8 and 15.7%, respectively, compared to 7.0 and 20.9% in the farmers' practice plots. Differences in *S. incertulas* larval damage estimates obtained from the pheromone-treated and farmers' practice plots in Warangal were reflected in grain yields, 4036 and 3715 kg/ha, respectively. Surveys of insecticide use indicated that 92% of smaliholders in Medchal applied insecticide at least once per season while in Warangal over 60% applied insecticide on two or more occasions. The data show that season-long control of *S. incertulas* comparable to that obtained with conventional insecticides can be achieved by mating disruption in smaliholder rice fields in India

2.21.3 Cultural control

Ploughing down or burning of stubbles just after harvest of the crop was found to destroy substantial stem borer larval population. Keeping the fields and bunds clean and destruction of weeds such as *Echinochloa colonum* reduced gundhi bug population. *Mnesethia laevis, E. crusgalli* and *Panicum* species were identified as alternate hosts for gall midge. Insect juvenile hormone, R-777 was found to inhibit metamorphosis of green leafhopper (Agrios, 1988). IRRI (1975, 1977) reported that resistant varieties of rice reduce the insect infestation.

2.21.4 Microbial control

Natural occurrence of microbial diseases of insect pests of rice resulted in the identification of three nuclear polyhedroses, two nematodes, two bacterioses and several mycoses of rice stem borers, leaf folders, leaf rollers, horned caterpillars, brown planthopers, green leafhoppers and grass hoppers. The technique of mass production of the fungus *Beauveria bassiana* and the entmophilic nematode *Parasitor habditis* sp. was standardized. Among these microbes, the bacterium Bacillus subtilis was highly effective, resulting in total mortality of lepidopteran rice pests within 48 hours.

Among several commercial formulations of *Bacillus thuringiensis*, *Thuricide* and *Dipel* were highly effective insuppressing the leaf roller as well as yellow stem borer population when sprayed incoincidence with the time of hatching of the larvae from the egg mass. These biocides persisted up to 15 days after spray and have a greater applicability, since they attack the target pest only, thereby helping in maintaining the ecological balance in the rice environment.

Parwez *et al*. (2006) observed a biometorological interaction between the stem borer and spider. There are several ways of using these agents for population regulation and the reduction of damage. The most common use has been similar to that of insecticides where immediate and possibly long term control is provided. There is little risk of the development of resistance to microbial agents. Microbial control agents have no adverse effects on parasites and predators (Razvi, 1991).

CHAPTER 3

MATERIALS AND METHODS

Materials used and methods followed during conducting the experiment have been mentioned and discussed under separate heads conforming to the objectives of the research work. The entire research work was carried out in the fields of Porabari, Salna, Gazipur, adjacence to Bangabandu Sheikh Mujibur Rahman Agricultural University, Gazipur, and different laborities of Bangabandu Sheikh Mujibur Rahman Agricultural University and Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka, during the boro season, November, 2010 to May, 2014.

3.1 Study area

Salna (Porabari), Gazipur

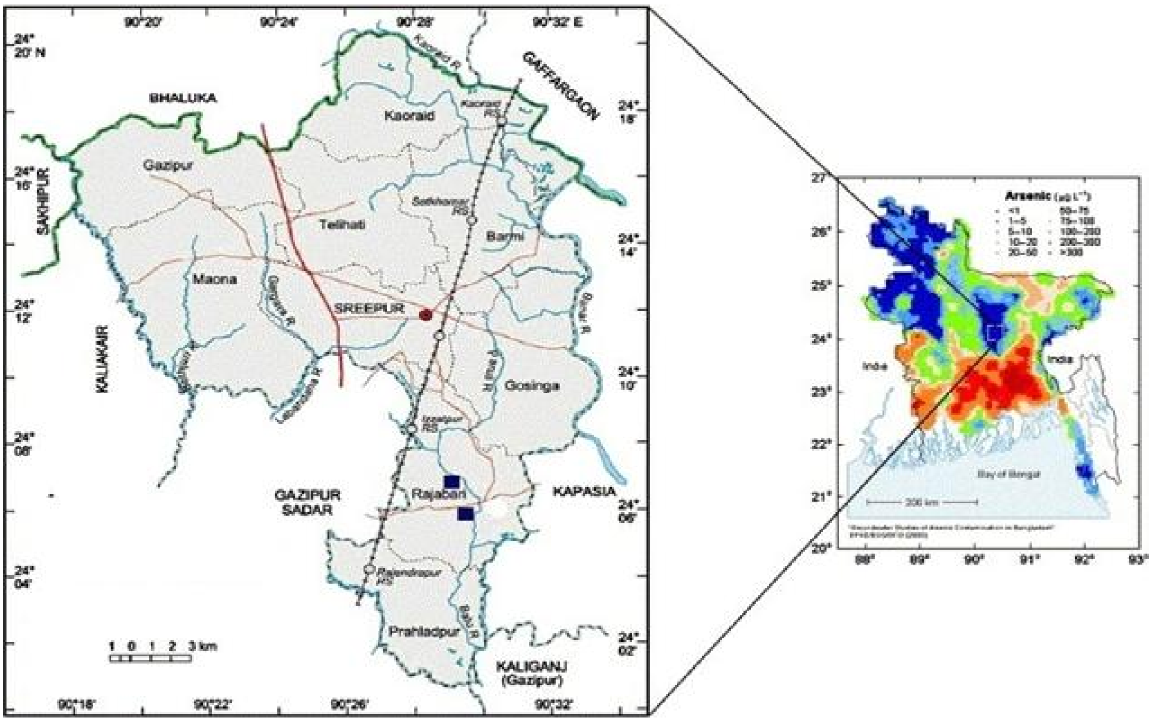


Plate 1. Study area location in Bangladesh specified in the Salna experimental station.

3.2 Description of the experimental site

3.2.1 Site and Soil

The experimental site belongs to the Tista flood plain and Active Tista flood plain of Agro Ecological Zone (AEZ) 8 &9. The field was a medium high land of silty loam texture with pH 5.58-6.8. The physical and chemical properties of the experimental soil are shown in the appendix I.

3.2.2 Location and climate

The experimental fields of Porabari, Salna, Gazipur, are located at 90^{0}24´06´´E. and 24^{0}05´06´´N. at a height of 18 meter above from the mean sea level. The area is under the sub-tropical climate, which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in Kharif Season (April-September) and scantly rainfall associated with moderately low temperature during Robi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during study period are presented in appendix II.

3.3 Experimental treatment

Experimental treatments consisted of seven modem rice varieties viz. IRATOM24, BlNA dhan5, BlNA dhan6, BRRI dhan28. BRRl dhan29, BRRl dhan36 and BADC1.

3.3.1 Description of the treatment

IRATOM24: It is an early maturity variety that takes about 140-150 days to mature during *boro* season and 125-135 days during *aus* season. Earliness facilities to harvest this crop variety before early flash flood and also escapes hailstorm. Plants are semi dwarf which do not lodge. Maximum grain yield potential is 8.0 tons/ha (av. 6.0 t ha^{-1}) in *boro* season and 4.0 tons/ha (av. 3.5 t ha^{-1}) in *aus* season (BINA, 2001).

BINA dhan5 and BINA dhan6: These two varieties were developed at Bangladesh Institute of Nuclear Agriculture, Mymensingh and were approved as transplant *boro* rice by the National Seed Board. In their developmental processes, seeds of F1 generation of cross between IRATOM24 and Dular were collected and irradiated with different doses of x-rays. After extensive field evaluation, they were finally selected from the progeny lines BINA 4-39-15-13 and BINA 4-5-17-19 and were named as BINA dhan5 and BINA dhan6 respectively. In *boro* season the growth period of BINA dhan5 is about 160-165 days from seed to seed. BINA dhan5 can produce a maximum grain yield of *8.5* t ha^{-1} (av. 7 t ha^{-1}). Grains are long, slender and bright in colour. Farmers can get more straw by cultivation of BINA dhan5. BINA dhan6 can produce a maximum grain yield 9 t ha^{-1} (av. 7.5 t ha^{-1}) which is comparable to hybrid rice. Grains are bright in colour (BINA, 2001).

BRRI dhan28: This variety was released by the BRRI in 1994. It was developed from the cross between BR6 (lR28) and purbachi. Genetic line number of this variety is BR 601-3-3-4-2-5. The plant height of this variety is 90 cm. it is recommended as an early variety of *boro* season. Rice grain is medium fine and white in colour. Its growth duration is 140 days. Under appropriate cultural practices, BRRI dhan28 can produce 5 t ha^{-1} of grain (BRRI, 1999).

BRRI dhan29: This variety is a high yielding moderately photoperiod sensitive cultivar of transplant *boro* rice. It was developed at Bangladesh Rice Research Institute from the cross between BR 90-2 and BR 51-46-5 and was approved by the National Seed Board. Its genetic line number was BR 802- 118-42. The plant attains a height of 100-120 cm, the leaves of the variety are dark green and erect and its growth duration is about 160 days. Under proper cultural conditions it may give 7.5 t ha^{-1} grain yields. Its fertilizer uptake capacity is high. BRRI dhan29 has been claimed to be the best of all modem rice cultivars in respect of yield and quality (BRRI, 1999).

BRRI dhan36: BRRI dhan36 is a high yielding moderately photoperiod sensitive cultivar of transplant *boro* rice. It was developed at Bangladesh Rice Research Institute from the cross between 1R64 and IR 35293-125-3-2-3 and was approved by the National Seed Board. Its genetic line number was 1R54791-19-2-3. The plant attains a height of 85-90 cm the leaves of the variety are dark green and erect and its growth duration is about 135-140 days. Under proper cultural conditions it may give more than *5* **t** ha^{-1} grain yield. Its fertilizer uptake capacity is high (BRRI. 1999).

BADCI: This variety was released by the Bangladesh Agricultural Development Corporation. The plant attains a height of 90 cm, It is recommended as an early variety of boro season. Grain is long and white in colour. Its growth duration is 145 days. Under appropriate cultural practices BADC I give a grain yield of 5-6 **t** ha^{-1}. This variety is resistant to storm and wind and it does not lodge.

3.4 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design with three replicate. The treatments were replicated thrice. Each block was divided into seven unit plots where seven varieties were allocated at randomly. The area of each unit plot was 10 m^2 (5m × 2m). The spaces between the blocks and between unit plots in the experiment were I m and *0.5* m, respectively. ‘There were 21 unit plots in the experiment.

3.5 Conduction of the experiment

3.5.1 Raising of seedlings

3.5.1.1Seed collection

Good quality seeds of BADCI were collected from BADC office, Dhaka, BRRI dhan28, BRR1 dhan29 and BRRI dhan36 were collected from BRRI, Gazipur and IRATOM24, BINA dhan5, BINA dhan6 were collected from BINA, Mymensingh.

3.5.1.2 Seed sprouting

Healthy seeds of each modern rice variety were soaked in water separately in different bucket for 24 hours. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing in nursery bed within 72 hours.

3.5.1.3 Preparation of seed bed and seed sowing

The seed bed was puddled with country plough, cleaned and labeled with ladder. Sprouted seeds were sown in the wet seed bed on December, 2010-2014. Seedlings were properly taken care of. Weeds were removed and irrigation was given in the seed bed as and when necessary.

3.5.1.4 Preparation of experimental land

The land was first opened with a tractor drawn disc plough. The land was irrigated. Later on the land was puddled thoroughly by ploughing and cross ploughing four times with a tractor followed by laddering to level the soil. The corners of the land were spaded. The weeds and stubbles were removed from the field to make the land ready for transplanting. Five soil samples were collected from different place of the experimental *area* for determining physical and chemical properties. The layout of the experimental field was done on January, 2010, 2011, 2012, 2013 and 2014 immediately after land preparation. After laying out, the unit plots were spaded and leveled again for transplanting.

Plate 2. Preparation of experimental land

3.5.1.5 Fertilizer application

The land was fertilized with only organic decomposed, no chemical fertilizers were used.

3.5.1.6 Uprooting of seedlings Wet seed beds were made by the application of water both in the morning and evening on the previous day before uprooting the seedlings.

Wet seed beds were made by the application of water both in the morning and evening on the previous day before uprooting the seedlings. Keeping as low as possible of mechanical injury to the roots, the seedlings were uprooted and kept on soft mud in shade before they were transplanted. The age of the seedlings was 35 days.

3.5.1.7 Transplanting of seedlings

Two seedlings per hill were planted on 1stweek, 2ndweek, 3rdweek and 4thweek of January, 2010-2014, maintaining hill and row spacing of 20 cm and 15 cm, respectively.

Plate 3. Transplanting of seedling

3.5.2 Intercultural operations

All intercultural operation was done as and when necessary.

3.5.2.1 Gap filling

Within one week of transplantation dead seedlings were replaced carefully by planting new healthy seedling from the same source.

Plate 4. Gap filling in fields

3.5.2.2 Weeding

Two times weeding were done by hand, one at 35 and second one at 60 days after transplanting (DAT).

3.5.2.3 Irrigation and drainage

A constant level of standing water up to 6 cm kept in early growth stage in the experimental field to enhance tillering. The field was drained out at 40 DAT and kept dry for about a week until simple cracks were seen in the field. Then again irrigation was provided and the water level was increase to some extent to discourage late tillering. The field was finally drained out again before 7 days of harvest to enhance maturity.

3.5.2.4 Harvesting

Different varieties were harvested at different dates during April-May, 2010-2014.

3.6 Sampling for data recording of the different phenological stages of rice

The following phenological stages of rice were studied during conducting the experiment

- Seedling stage
- Vegetative stage /Active tillering stage
- Early reproductive /pre flowering / panicle initiation stage
- Reproductive /Heading/ Flowering stage
- Post reproductive /Maturity stage

Four times sampling were done, first at maximum tillering stage (active tillering), second at panicle initiation stage (when panicle primodia was about 2mm in length), third at heading stage (when 9O% panicles were headed)/reproductive stage and finally at maturity stage (post reproductive). At each sampling five random hills were first counted for their total tillers and then their number were averaged. Out of those five hills two hills were taken for recording the following data.

Plate 5. Vegetative stage / Tillering initiation stage.

Plate 6. Early reproductive stage / pre flowering stage

Plate 7. Reproductive stage / Heading stage

Plate 8. Post reproductive stage/ Maturity stage

3.6.1 The following plant morphological characters were recorded

Plant height (cm)

Number of total tillers hill^{-1}

Number of leaf per tiller

Length of flag leaf

Width of flag leaf

Length of second leaf

Width of second leaf

Number of leaf hairs per square centimeter

3.6.2 The following Plant physiological characters were observed

3.6.2.1 Total dry matter

Each time of sampling, all the green leaves were separated hill^{-1}. The leaves of two hills were separately dried in electric oven at 80°C ± 5°C for 48 hours by putting them in brown paper bag. Stems were also dried in the same manner. Panicle at heading and maturity for growth data collection were cut at their panicle knot and were dried in oven following the same procedure as leaves and stem. After proper drying their weights were taken by weighting in electronic balance hil^{-1} basis.

Total dry matter production data were calculated by adding all the plant parts of a hill together i.e., leaf dry weight, stem dry weight and or panicle dry weight. Finally it was converted into per unit basis and it was used to estimate constituents of total dry matter for calculating leaf area index (LAI), Crop growth rate (CGR), Net assimilation rate (NAR).

3.6.2.2 Leaf Area Index (LAI)

Leaf area measurements are often needed as an index of growth and for assimilation and transpiration determination in agronomic and plant physiological studies including plant growth and evapotranspiration modeling.

It is the ratio of total surface area of leaves of a unit land area (Watson, 1978). It is expressed as:

$$LAI = \frac{LA}{P}$$

Where, LA = Total leaf area (cm^2)

P = Ground area (cm^2)

The rate of photosynthesis depends on the LAI and structure of the canopy and photosynthetic per unit leaf area (Evans, 1975).

3.6.2.3 Crop Growth rate (CGR)

Crop growth rate is the ratio of dry matter production per unit area of land per unit time. It is the product of NAR and LAI. It is indicated that CGR is slow at the beginning of the season and progressively increased to a pick value and then declined sharply. It is positively correlated with LAI and NAR and it increased with LAI. It is expressed as:

$$CGR = \frac{1}{P}\frac{W_2 - W_1}{T_2 - T_1} \quad \text{g cm-2d-1}$$

Where, P = Ground area (cm-2)

W_1= Total dry weight at time T1

W_2 = Total dry weight at time T2

T_1 = First time

T_2= Final time

3.6.2.4 Relative Growth Rate (RGR)

The relative growth rate of plants is defined as the increase of plant weight per unit of weight present per unit of time. Therefore, it reflects the inherent efficiency of the growth process irrespective of plant *size* and provides a good basis for comparing treatment effects (Evans, 1975). It is expressed as:

$$RGR = \frac{l_n W_2 - l_n W_1}{T_2 - T_1} \quad \text{g g-1 d-1}$$

Where, l_n = Natural logarithm

W_1 = Total dry weight at time T_1

W_2 = Total dry weight at time T_2

3.6.2.5 Net Assimilation Rate (NAR)

It is defined as the increase in dry weight per unit time per unit leaf area present and is the most important index of mean photosynthetic efficiency of a plant under a particular environment. It is expressed as:

$$NAR=\frac{W_2 - W_1}{T_2 - T_1} \text{ X } \quad g\ cm^{-2}\ d^{-1}$$

Where, LA_1 = Total leaf area at time T_1
LA_2 = Total leaf area at time T_2

3.7 Sampling for grain growth characters

When heading was started, 20 random hills were selected in each plot. From each hill, two panicles preferable from main stem were marked which headed on the same day. At each sampling two panicles were sampled from the selected hill. Then flag leaf; second leaf, third leaf and other leaves were separated from basal stem and grains were separated from panicles and its oven dry weights were recorded. There were all together five samplings with an interval of seven days. The spikelets of lower, middle and top rachis branches in the panicles were counted in each sampling and their weights were also recorded. Finally they were averaged per panicle basis.

3.8 Sampling for yield and yield contributing characters

Harvesting was performed depending on the maturity of different varieties. The date of harvesting was confirmed when 90% of the seeds became golden yellow in colour. Different varieties were harvested at different dates during April-May 2010-2014. At maturity stage, 25 random hills were harvested at the base. Out of 25 hills, five hills were selected for data collection all the following items except grain, straw, biological yield and harvest index were recorded from the rest 20 hills. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The harvested crops were threshed manually and fresh weight was taken plot wise. The grains were cleaned and dried to a moisture content of 14%. Straw were sun dried properly. Finally grain and straw yields per plot were recorded and converted into ton ha^{-1}.

Plate 9. Supervision of experiment field design by the guide

Plate 10. Field advices are being taken to exercise the experimental design with other scientists of EBBL.

3.8.1 The following parameters were study for yield data collection

3.8.1.1 Number of effective tillers per hill

The tillers which had at least one grain was considered as effective tillers.

3.8.1.2 Number of total spikelet per panicle

The number of grain panicle^{-1} plus the number of sterile spikelets panicle^{-1} gave the total number of spikelets panicle^{-1}. Number of grains and unfilled spikelets were conducted from each panicle. Presence of any food material in the spikelets were counted as grain where lacked any food materials inside were considered as unfilled spikelets.

3.8.1.3 Number of unfilled spikelet per panicle

3.8.1.4 Number of filled grain per panicle

3.8.1.5 Number of unfilled grain per panicle

3.8.1.6 Panicle length

Measurement was taken from basal node of the rachis to the apex of last grain of each panicle.

3.8.1.7 1000 grains weight

Weight of 1000 random filled grains was determined by an electrical balance from the dried seed of 5 hills. Finally the weight was converted at 14% moisture level taking moisture % reading by a moisture meter (GMK-303 RS, JEEWON MACHINERY CO. LTD. JAPAN).

3.8.1.8 Grain yield

The grain yield was measured from the harvest of 20 hills by threshing, drying and winnowing and then the moisture % was determined and finally converted at 14% moisture level and per hectare basis.

3.8.1.9 Straw yield

The sun dry straw was weighted from the same sample of 20 hills from which grain yield was recorded.

3.8.1.10 Biological yield

Biological yield *was* calculated by using the following formula

Biological yield = Grain yield (**t** ha^{-1}) **+** straw yield (t ha^{-1})

3.8.1.11 Harvest Index

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al*., 1985) Harvest index (%) = $\frac{\text{Grain yield}}{\text{Biological yield}}$ x 100.

Plate 11. Spikelet separation from panicle.

3.9 Biological study of yellow rice stem borer (*Scirpophaga incertulas*)

Primary culture was established by collecting the pupae of *S. incertulas* from the paddy fields and was kept in a mating cage of 18 cm diameter and 3 cm height. After the emergence, the male and female adults were allowed for mating and the mated females were placed into the cage of size 50 × 50 × 60 cm. After oviposition, the rice leaves containing the egg masses were clipped off and their bases were wrapped in moist cotton to keep them fresh until hatching. These were then placed on a moist filter in the petriplates of diameter 10 cm and were exposed for embryonic development. The dates on which eggs hatched were recorded. On hatching, first instar larvae were detected from the egg mass with the help of hand lens and collected with the help of camel hair brush, following the method of Saxena *et al*. (1990).

Plate 12. Oviposition cage on practice in the field condition.

At 25 – 30 days after infestation (DAI) earthen pots containing paddy hills with white ears harbouring late larvae or pupae (pale yellow in colour, near root zone) were kept in the insect cages (50 × 50 × 60 cm). After formation of pupae, the stems were split open to facilitate adult emergence. Pupal period was recorded as the time between formation of pupa and adult emergence. The pupa thus obtained was kept in a plastic cage (18 cm diameter and 8 cm length) for adult emergence.

Emerged adults were separated as males and females and pairs of male and female were kept separately in cage containing 30 day-old potted seedlings. Adults were provided with five percent sugar solution in a cotton swabs. The egg masses laid by the female were then collected and reared to study the incubation period, fecundity and hatching percentage. Once hatching was completed, the egg masses were dipped in 75 percent alcohol and the hairs were removed. The eggs were then separated out with the help of a fine camel hair brush and the number of hatched and unhatched eggs was counted under a microscope and the hatching percentage and fecundity was calculated. Incubation period was recorded as the time between egg laying and hatching.

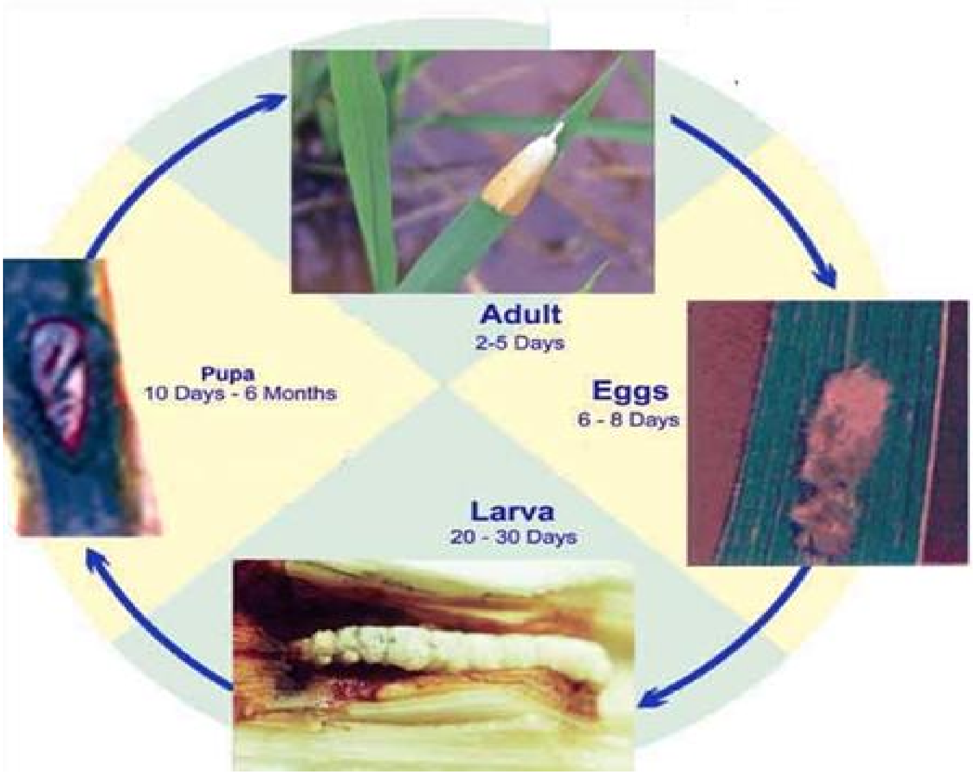


Plate 13. Life stages of yellow rice stem borer (*Scirpophaga incertulas*)

Plate 14. Egg mass of yellow rice stem borer (*Scirpophaga incertulas*) at vegetative stage of rice

Plate15. Adult, egg and larvae of yellow rice stem borer (*Scirpophaga incertulas*)

3.10 Identification of different species of rice stems borers present in the rice stubbles

Stem borers were identified on the basis of morphological characteristics as described by Alam (1967); Pathak (1968); Banerjee and Pramanik (1967). The matured stem borer larvae that infested the rice plants were collected and reared in the rice stems in the glass cages till they became adult for identification.

The adult *Scirpophaga incertulas* was a small moth of straw yellow colour. The fore-wings were birght yellowish brown with a clear single black spot in the center.

The adult of *Chilotrae*s species was grey in colour with veins prominent in the fore-wings. The male moth had black patches on the fore-wings. The antennae were long and filamentious.

The larvae of *Chilotraes* spp. were identified by five light brown parallel stripes on their dorsal body surface. The larvae of *Scirpophaga incertulas* varied from creamy or yellowish white to dirty white. The larvae of *Sesamia inferens* were much more robust than any of the previously mentioned borers and were of pink color.

3.11 Identification of stem borer-infested rice tillers of the rice stubbles

The stem borer-infested rice tillers were easily recognized by bisecting the rice tillers into two equal halves from top to bottom. The infested tillers showed inside the lacerated and damaged of the stem including the presence of borer-excretes. Sometimes the dead or live borer larvae were observed feeding inside the tillers.

Plate 16. Stem bisection for identifying the infestation of yellow rice stem borer (*Scirpophaga incertulas*)

3.12 Field studies (in rice stubbles) on the overwintering of yellow rice stem borer (*Scirpophaga incertulas*)

The samplings of the rice stubbles were made during December to February 2010-2014. Every day several samples of boro rice -stubbles (about 30 samples) were collected at random from the selected field. Each sample contained one hill of rice stubbles and each hill consisted of approximate 6 to 12 rice tillers and total number of infested tillers was counted separately every day. Each infested tiller and infested tiller with live borer larvae inside was confirmed by bisecting the tillers. Then the percentages of infested tillers and the percentages of infested tiller with live borer larvae inside were averaged together for each 15 days samples of rice tillers.

3.13 Laboratory studies (in rice stubbles) on the over wintering of yellow rice stem borer (*Scirpophaga incertulas*)

Field collected rice stubbles were brought into the laboratory and the live borer was dissected out of the infested stem. For each larva, one fresh stem of about 6 cm. in length was cut and placed inside the Petridis. Each larva was individually allowed to enter into each of the 6 cm cut fresh rice stem. The larvae in the paradises were examined every day and their percentages of mortality, survival and emergence adults during December to February (winter season) were recorded.

3.14 Laboratory studies on the distribution pattern of the larval death and adult emergence of yellow rice stem borer (*Scirpophaga incertulas*) during different months in the winter season

The distributions pattern of the larval death and adult emergence of the rice stem borers was studied in the winter season. The live borer larvae of *Schirpophaga incertulas*, was put separately inside pertridishes containing freshly cut 6 cm pieces of fresh rice stems. The number of larvae that died and the number of larvae that emerged as adults during December to February was examined in the petridishes and recorded together for each 15 days period.

3.15 Estimation of the population of yellow rice stem borer (*Scirpophaga incertulas*) of live larvae in the rice stubbles in different months during winter season

A total of 980 infested rice tiller (stubbles), 151 tillers during December (1-5), 256 tillers during December (16-31), 138 tillers during January (1-15), 110 tillers during January (16-31), 156 tillers during February (1-15) and 169 tillers during February (16-29) were dissected. The total number of live larvae of *Schirpophaga incertulas* found within the bisected rice tillers was recorded separately. Then the proportion of the larvae of each species was calculated separately for each 15 day interval period, during winter starting from December 1 and ending in February.

3.16 Nature of damage done by yellow rice stem borer (*Scirpophaga incertulas*)

While feeding inside the stem, the caterpillar of the rice stem borer cuts off the growing part of the plant from the base causing it to die. This condition is commonly known as 'dead heart' (DH) indicated by dried middle leaf or dried foliage occurring in young plants. These 'dear heart' were usually found about 30 days after transplantation. When the stem borer-injury occurs after the period of maximum tillering, which is later in the development of the plant and referred to as the reproductive or flowering stage, empty whitish panicles are formed which are commonly known as 'white heads' (WH). This was another external symptom by which the stem borer injury was estimated during the different phonological stages.

Plate 17. Affected tiller at early vegetative stage (Dead heart) of rice

3.16.1 Estimation of 'dead heart' (DH) for different rice varieties.

The samplings were made for dead hearts usually 30 days, 60 days, and 90 days after transplantation. A total of 90 samples were collected at random from the three replications of each plant type (Rice varieties) in every sampling time. Each sample consisted of one rice hill and each hill consisted of approximately 8 to 20 rice tillers. These samples were brought to the laboratory and total number of tillers and all the 'dead hearts' were counted separately for each plant type, each 'dead heart' was confirmed by bisecting the tiller and detecting the borer-injury.

3.16.2 Estimation of 'white head' (WH) for different rice varieties

The sampling method for estimating 'white heads' was the same as described for 'dead hearts' in the previous section. Sampling for 'white heads' were made during half-ripen stage of rice panicles. Samples were collected at random from different plot of each plant type. As before a lot of 90 samples were collected from 3 replications of each plant type. Each sample consisted of one rice hill and each hill consisted of one rice hill and each hill consisted of approximately 8-20 effective tillers. Each 'white head' was confirmed by bisecting the tillers and detecting the pest-damage inside.

Plate 18. Sign of White-Head

3.17 Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of different rice varieties in boro season

Thirty days after transplanting first sample was taken. A total of 25 hills were uprooted from each plot per week. The plants were selected by rows and pace randomly. First, random number in 5 rows was selected then pace numbers were randomly selected i.e. a total 5 hills per row. In this way 5 hills per row were collected i.e. a total of 100 hills were collected weekly till harvest. During this season 12 weekly samples were taken.

The collected hills were washed thoroughly and taken with proper care during uprooting as well as washing and, so that they were not damaged. The sample was then brought to the laboratory in four separate bundles with proper tags. Then tillers of each hill were thoroughly examined for egg mass, "dead heart" (DH), and "white head" (WH). After that the tillers were dissected to find out infested tillers without apparent symptoms (IT WAS). Findings were recorded hill by hill. Total number of larva, pupae from infested hills and growth stages of the crop observed during dissections were also recorded carefully. Growth stages of larvae were also noted.

Separate direct observation of DH and WH were taken during maximum tillering and at maturity of the crop respectively. In field, observations of every alternate two rows were made for DH and WH so that in all 50% hills were observed for DH or WH. The percentage of damage was calculated according to the formula of Gomes (1972).

Comparative crop injury at three phonological stages were marked: i) active tillering stage (vegetative phase), ii) pre flowering or early reproductive stage (panicle initiation to booting) and iii) flowering i.e. late reproductive stage (post booting to maturity).

Infested hills, infested tillers, ITWAS, numbers of DH and WH were compared in relation to three phenological stages. Numbers of DH and WH obtained from direct filed count were compared between these two characters at maximum tillering and at maturity.

The light trap was fitted with a 20 Watt fluorescent light at one meter above from the ground. The total number of rise stem borer moths collected each week was counted and data were computed in the following way.

3.18 Coincidence of phenological stages of plant (*Oryza sativa)* and the life stages of insect (*Scirpophaga incertulas*) in boro season

35 days old seedlings of different rice varieties were transplanted at early- January, mid-January and late- January from 2010-2014. The duration of different phenological stages of each rice variety were counted and at the same time the life stages of *S. incertulas*

appeared at each phenoogical stage was also recorded. The sampling for coincidences between two biotic aspects (plant and insect) was same as described for phenoogical stages of rice and identification of stem borer infested rice tiller in the previous sections.

3.19 Control measures of yellow rice stem borer (*Scirpophaga incertulas*)

3.19.1 Estimation of the effect of phenological stages of different rice varieties appeared at different transplanting time on the incidence of *S. incertulas*

35 days old seedlings of different rice varieties were transplanted at early- January, mid-January and late- January from 2010-2014. The stem borer population was estimated in terms of arrival time of adult *S. incertulas,* number of egg masses presence, and percentage of incidence of DH or WH after transplanting from each plot. The sampling method was same as described for assessment of crop injury caused by *S. ncrtulas* in the previous section.

3.19.2 Estimation of the percentage of borer infested rice tiller of different rice varieties with the stubbles ploughing and not ploughing the experimental plots after immediate harvesting.

The sampling for estimation of the percentage of borer infested tiller was made in the rice approximately 15 days after the harvesting of the different rice varieties. The sampling method was same as described for assessment of field studies on the over wintering of S. *incertulas.*

3.19.3 Estimation of the percentage of YSB infested rice tiller after flooding and not flooding the experimental plots after immediate harvesting.

The sampling for estimation of the percentage of borer infested rice tiller was same as described for assessment of field studies on the over wintering of *S. incertulas.*

3.20 Statistical analysis

All the recorded data were compiled and appropriate statistical analysis was made following the analysis of variance technique. The differences among the treatment were adjudged with Duncan's Multiple Range Test (DMRT) using a statistical computer packages (MSTAT) (Gomez and Gomez, 1984).

CHAPTER 4

RESULT AND DISCUSSION

The results of the present study have been presented and discussed parameter wise in this chapter. Data have been shown in Tables and Graphs. The data used for the construction of graphs in the text are also shown in appendices for better understanding.

4.1 Phenological stages of individual seven rice varieties attained the following physiological characters in boro season

4.1.1 Total dry matter (TDM)

Dry matter of vegetative parts hill^{-1} was significantly influenced by variety at all the phenological stages (Appendix III). At maximum tillering stage the highest TDM hill^{-1} was observed in BRRI dhan29 (32.67 g) and the minimum in BRRI dhan36 (23.50 g). At panicle initiation, heading and maturity stages dry matter of BRRI dhan29 remained maximum (.36.45, 45.90 and. 54.16g hill^{-1}), A similar result was reported by Vergara *et al.* (1964) who have reported that the total dry matter of the plants increased with time, initially the increase of dry matter was slow, then it reached in peak. It was observed that the BRRI dhan29 accumulated the maximum total dry matter at all the phenological stages which was statistically dissimilar to other varieties and BRRI dhan3ó produced the lowest total dry matter at all the phenological stages. It range was 23.50-32.67, 26.88-36.45 and 35.89-54.16 g hill^{-1} respectively during maximum tillering stage, panicle initiation stage and heading stage. The other varieties gave intermediate values (Fig.1 and Appendix X). Results revealed that dry matter accumulation increased with the increase of time and initial increase of dry matter was slow. It was accelerated on later stages and reached in the peak at maturity stage. The significant variation in dry matter production among the cultivar was also reported by Arjunan *et al.* (1990). Generally dry matter was positively correlated with grain yield (Chen *et al.*, 1991).

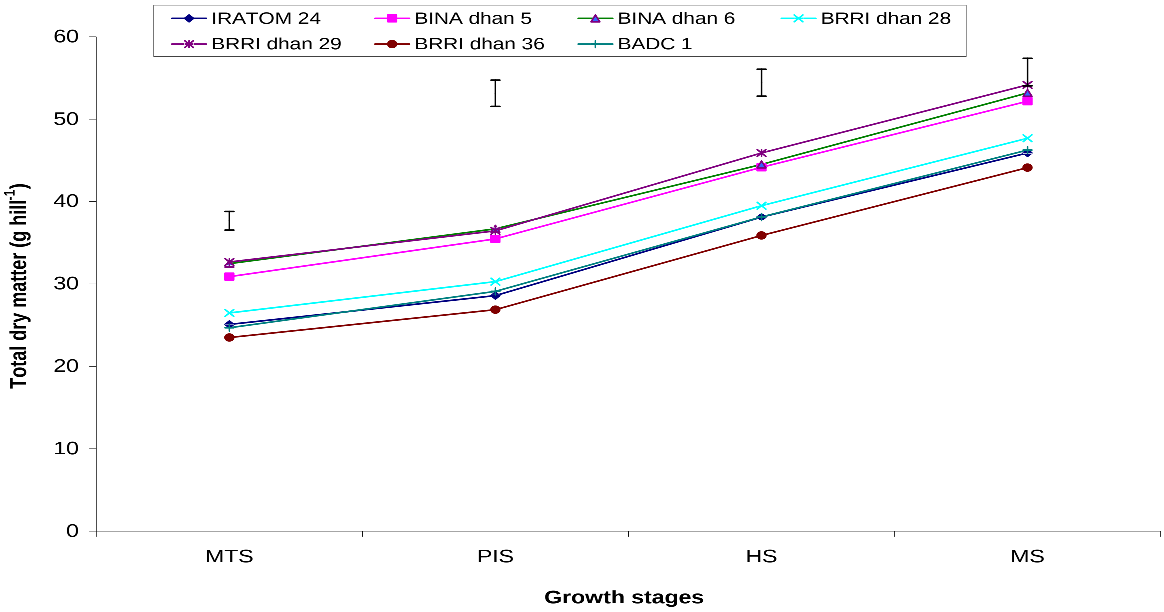


Fig. 1. Total dry matter production at different phenological stages of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05. MTS =Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage and MS = Maturity stage

4.1.2 Leaf area index (LAI)

Leaf area index (LAI) differed significantly at all the phenological stages (Appendix IV). It was observed that the BRRI dhan29 produced the maximum LAI at all the phenological stages and at heading stage it was highest (4.50) which was statistically dissimilar to others. The lowest LAI (2.08) was produced by BRRI dhan36 during maturity stage which was statistically identical to BADC1 (2.15) (Fig.2 and Appendix XI). Results showed that, the LAI was increased as growth advances and reached into a maximum at heading stage and then declined at maturity stages. The leaf area index for all varieties was highest at heading stage and lowest in maturity stage and intermediate at maximum tillering stage and panicle initiation stage. LAI declines as the lower leaves die (Tsai, 1984; Yoshida, 1981).This result was similar to the varieties studied in this experiment. This partially confirms the reports of Manna (1987) who have reported that LAI was highest at just after heading then declined.

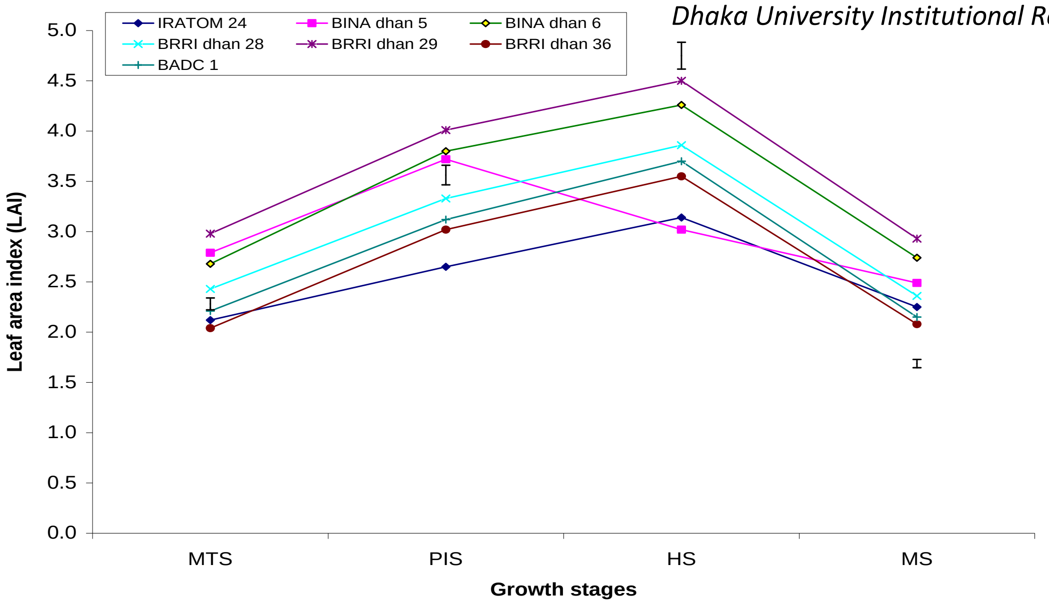


Fig. 2. Leaf area index (LAI) during different phenological periods of seven rice varieties in boro season

4.1.3 Crop growth rate (CGR)

Crop growth rate (CGR) influenced significantly due to the varieties at all the intervals of phenological stages (Appendix V). Maximum CGR in different phenological periods like maximum tillering stage (MTS) to painicle initiation stage (P1S), panicle initiation stage (P1S) to heading stage (HS) and heading stage (HS) to maturity stage (MS) were observed 9.18, 23.43 and 15.50 g m^{-2} d^{-1}respectively in the varieties BRRI dhan28, BADCI and BADCI. On the other hand minimum CGR during the same periods were 6.35, 15.04 and 11.13 g m^{-2} d^{-1}respectively in the varieties BRRI dhan29, BINA dhan5 and BINA dhan5. During MTS to PIS the CGR of BRRI dhan28 was similar to BADCI but dissimilar to other and during P1S to HS, HS to MS the CGR of BRRI dhan36 was statistically similar to BADCI (Fig.3 and Appendix XII). This result was in agreement with Kabaki *et al.* (1992) who have reported that CGR *of indicia* varieties were highest at heading and after heading it declined markedly. Higher CGR of the modern varieties at PI stage to heading stage as shown in the results, might be due to the higher LAI associated with higher NAR and decrease of CGR from heading to maturity stage decreasing LAI following senescence of older leaves (Weing and Chen 1988). This result was similar to the varieties studied in this experiment. From the experimental results it was found that varietal differences of CGR were significant which agreed with Tsai (1991); Paranhos *et al.* (1997) and Motamatsu *et al.* (1990).

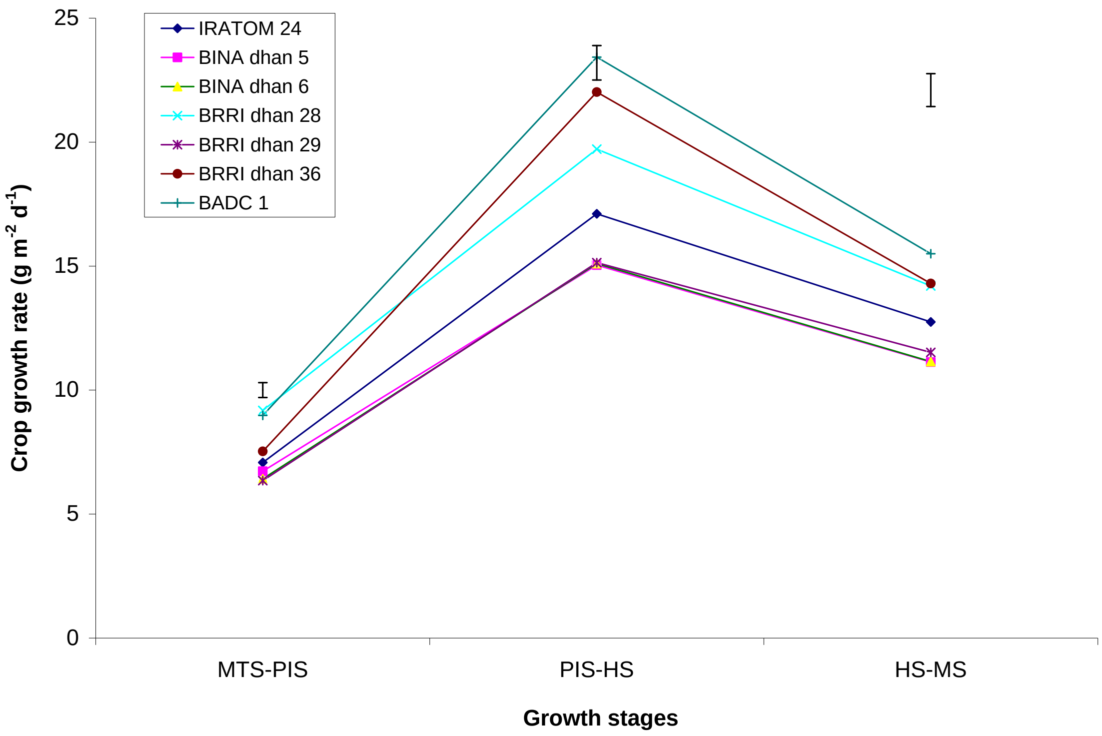


Fig. 3. Crop growth rate (CGR) during different phenological periods of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05. MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage and MS = Maturity stage

4.1.4 Relative growth rate (RGR)

Relative growth rate (RGR) influenced significantly due to the varieties at all the intervals of phenological stages (Appendix V). Maximum RGR in different growth periods like MTS to P1S, PIS to HS and HS to MS were observed 0.050, *0.067* and 0.022 g g^{-1} d^{-1}, respectively in the varieties BRRI dhan3ó, BRRl dhan36 and BADC1. On the other hand minimum RGR during the same periods were 0.014, 0.021 and 0.0 11 g^{-1} d^{-1} in the varieties BRRI dhan29. The results revealed that maximum values of RGR attained at panicle initiation to heading stage and then decreased with the advanced of time, might be due to the higher LAI associated and decreasing LAI following senescence of older leaves which was supported by (Weing and Chen, 1988). BRRI dhan36 possessed the highest RGR throughout the whole phenological period which was statistically identical to BADCI, BRRI dhan28 and IRATOM24 at maximum tillering to panicle initiation stage and BADCI and BRRI dhan28 heading to maturity stage and only BADC1 at panicle initiation to heading stage. On the other hand BINA. dhan5, BINA dhan6 and BRRI dhan29 were statistically identical at all the intervals and produced the minimum RGR at all the phenological stages as compared to

BRRI dhan36, BRRI dhan28, BADC1 and IRATOM24 might be due to the higher intervals among the growth stages (Fig.4 and Appendix XII). The results of the present study is in agreement with the results of Khan (1981) who stated that maximum RGR observed during the around heading stage and declined rapidly with the advancement of phenological stages since the photosynthesis produced in the leaves were consumed rapidly elongating ones. This result is also partially supported by the result on Salam *et al.* (1987).

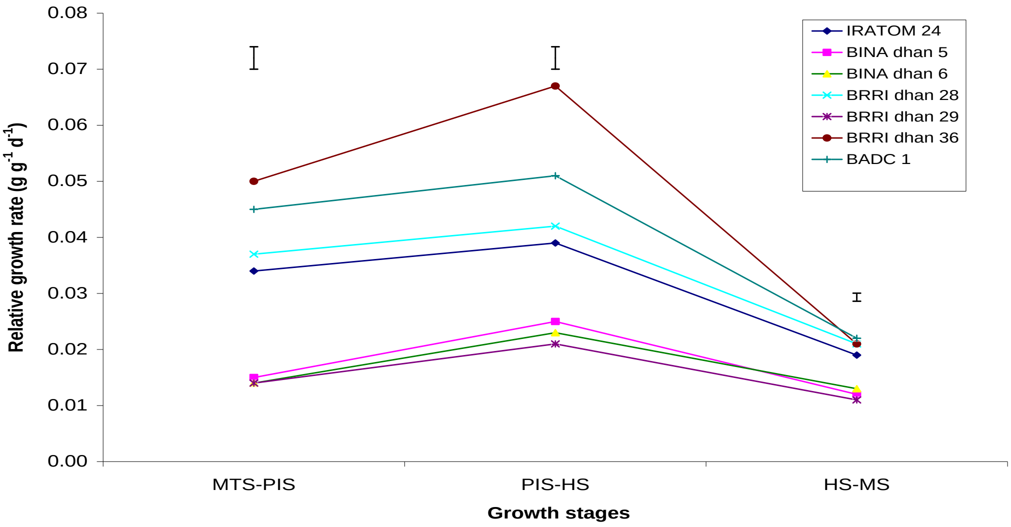


Fig. 4. Relative growth rate (RGR) during different phenological periods of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05 MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Headingstage and MS = Maturity stage

4.1.5 Net assimilation rate (NAR)

Significant variation in net assimilation rate (NAR) was observed during maximum tillering to panicle initiation and heading to maturity stages (Appendix V). Results indicated that BADCI produced the maximum NAR (3.43, 5.95 and 5.44 g m^{-2} d^{-1}) throughout the whole phenolgical period which was statistically non identical to others at all phenological stages . During heading to maturity stage, BRRI dhan29 produced the low amount of NAR (3.19 g m^{-2} d^{-1}) which was statistically identical to BINA dhan6. It was found that the NAR was numerically highest for all varieties during panicle initiation to heading stage and then declined (Fig.5 and Appendix XII). This results obtained from the present study are consistent with the results of Buttery (1970) who reported that the NAR of a crop declined gradually with increasing LAI. These results were also supported by Koller (1970). In the present results NAR tended to increase during panicle initiation to heading stage which might be assigned to increase sink demand and grain photosynthesis. Similar results were observed by Pandey and Singh (1980).

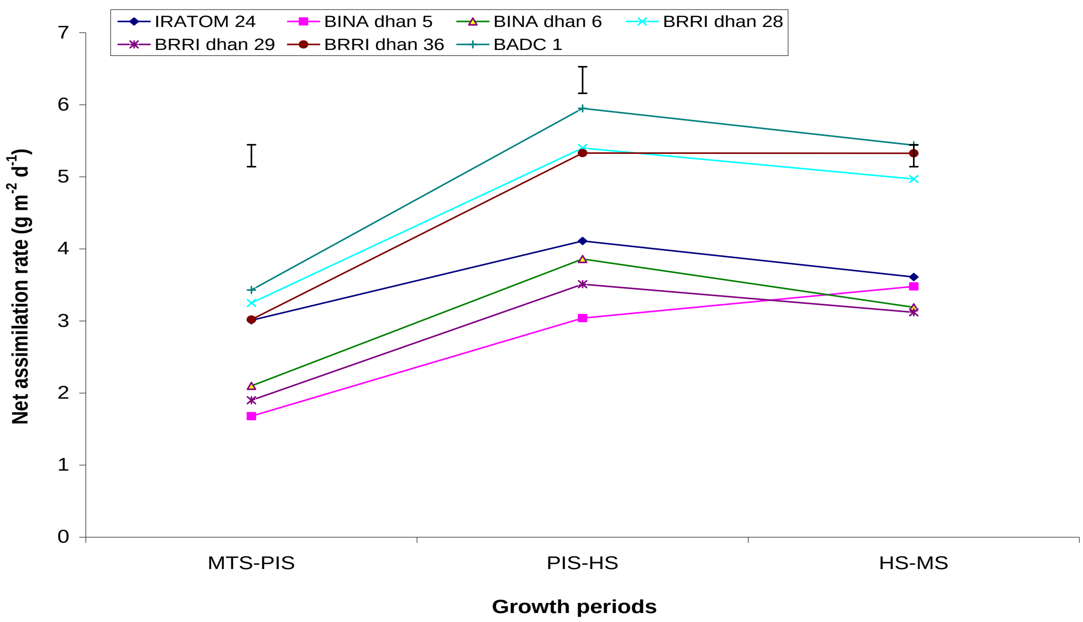


Fig.5. Net assimilation rate (NAR) during different phenological periods of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05. MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage and MS = Maturity stage

4.2 Phenological stages of individual seven rice varieties initiated the following grain growth patterns in boro season

4.2.1 Grain growth pattern in top rachis of the panicle

Weight of spikelets on top rachis showed significant variation among the varieties in all samplings (Appendix VI). At 10 days after heading (DAH), the highest individual weight of spikelet (13.47mg) was obtained in BRRI dhan29 and the lowest was in BRRI dhan36 (6.39 mg). At 38 DAH maximum weights (35.36 mg) was also observed in BRRI dhan29 and minimum (25.20 mg) was in BRRI dhan36 (Fig.6 and Appendix XIII). The result indicated that the weight of top rachis individual spikelet of BRRI dhan29 was maximum among the varieties in all samplings and BRRI dhan36 was minimum for same period. It was found that as a natural process of grain development in the panicles. Weight of grain development in the panicle, weight of grain increased gradually up to last sampling. But variation among varieties occurred due to current assimilate storing characteristics of varieties and also due to translocation differences in carbohydrates from stem to grain during the ripening period. It could be observed from the data presented in Fig. and Appendix that in later stage, increment of grain weight rate become slow. It might be due to gradual decline in photo assimilates supply from photosynthesis of leaves especially the top leaves.

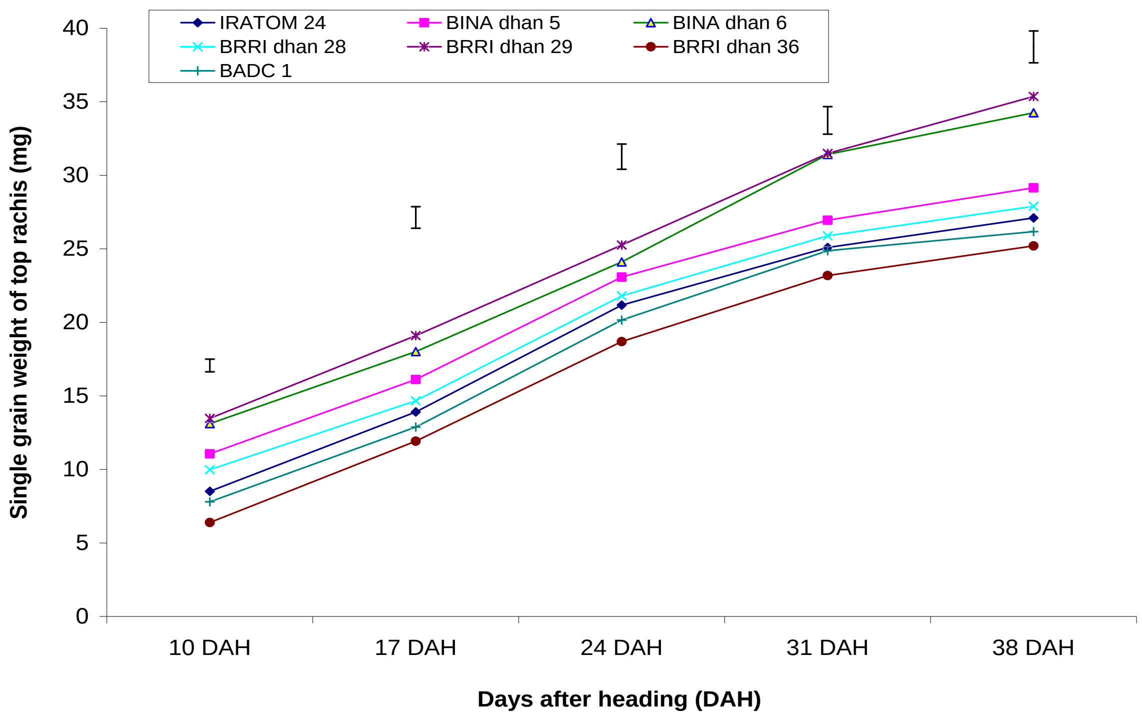


Fig. 6. Growth pattern of top rachis grain of the panicle at different days after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05.

4.2.2 Grain growth pattern in middle rachis of the panicle

Individual weight of middle rachis spikelet exhibited their differences significantly among varieties (Appendix VII). It was found that the weight of middle rachis individual spikelet of BRRI dhan29 was maximum among the varieties in all sampling and BRRI dhan36 was almost minimum. Individual weight of middle rachis of other varieties was intermediate. At 38 days after heading individual weight of middle rachis of BRRI dhan29 was highest (30.22mg) and other varieties were statistically dissimilar (Fig.7 Appendix XIV). The results showed that middle rachis individual spikelets was of all the varieties were a little bit smaller in size and it reflected its weight. Varietal differences regarding individual grain weight of middle rachis of the panicle might be due to their differences in assimilate accumulation capacity and also due to genetic makeup.

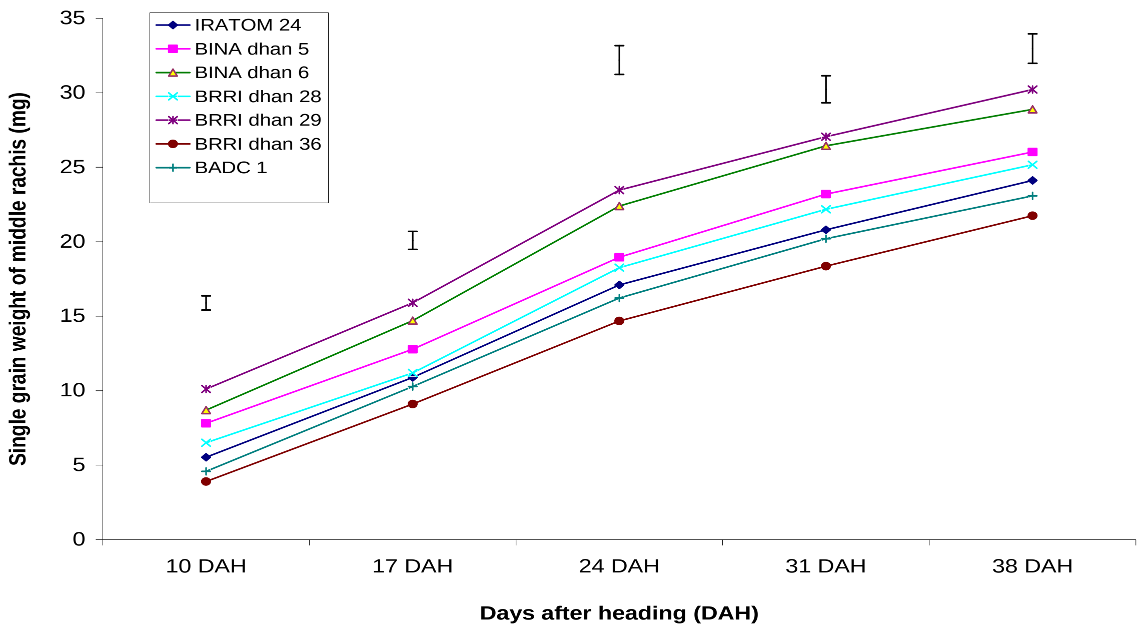


Fig.7. Growth pattern of middle rachis grain of the panicle at different days after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05.

4.2.3 Grain growth pattern in lower rachis of the panicle

Individual weight of lower rachis spikelet was significantly affected by variety at all samplings (Appendix VIII). Among the seven varieties BRRI dhan29 had the maximum single grain weight (7.89 mg) at 10 days after heading (DAH) and the lowest weight (3.75 mg) on same day was observed in BADC1 which was statistically dissimilar to others. At final sampling of 38 DAH, the BRRI dhan29 produced the highest grain weight (27.26 mg) while BRRI dhan36 produced the lowest (21.18 mg) single grain weight but it was statistically identical to BADCI and IRATOM24 (Fig.8 and Appendix XV). Individual grain weight increased with growth duration up to maturity in every variety but weights remained different for different varieties. These results are in conformity with those obtained by Cia and Wu (1993) who reported that dry matter accumulation at each grain growth stage was significantly affected by grain weight.

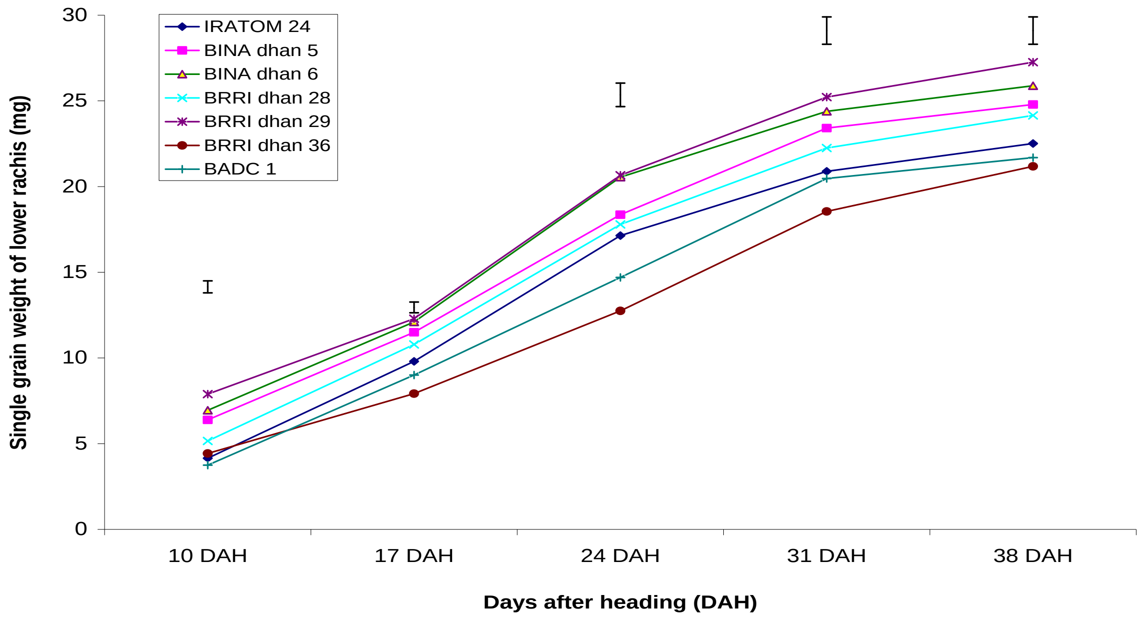


Fig. 8. Growth pattern of lower rachis grain of the panicle at different days after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05.

4.2.4 Grain growth rate in top rachis of the panicle

Variety influenced grain growth rate (GGR) significantly during the period of 25 - 31 DAH, 32-38 DAH and non significantly during the period of 10-17 DAH and 18-24 DAH (Appendix VI). During 10 - 17 DAH numerically the highest GGR (0.80 mg grain^{-1} d^{-1}) was found in BRRI dhan29 and the lowest GGR (0.67 mg grain^{-1} d^{-1}) was in BRRI dhan28. During the period of 25-31 DAH maximum grain growth rate (1.00 mg grain^{-1} d^{-1}) was observed in BINA dhan6 and minimum (0.55 mg grain^{-1} d^{-1}) in BINA dhan5 which was statistically similar to RRRI dhan28 and IRATOM24, but during the period of 32 - 38 DAH, the highest grain growth rate (0.55 mg grain^{-1} d^{-1}) was found in BRRI dhan29 and the lowest (0.18 mg grain^{-1} d^{-1}) in BADC1 which was statistically non identical to others (Fig.9 and Appendix XIII). The result indicated that the grain growth rate increase up to 18- 24 and then declined and minimum in 32- 38 DAH for all varieties. It might be due to gradual declined in photo-assimilates supply leaves especially the top leaves *and* also ceased if resume translocation from leaf sheath and stem. These results were in agreement with that of Kailasam *et al.* (1989).

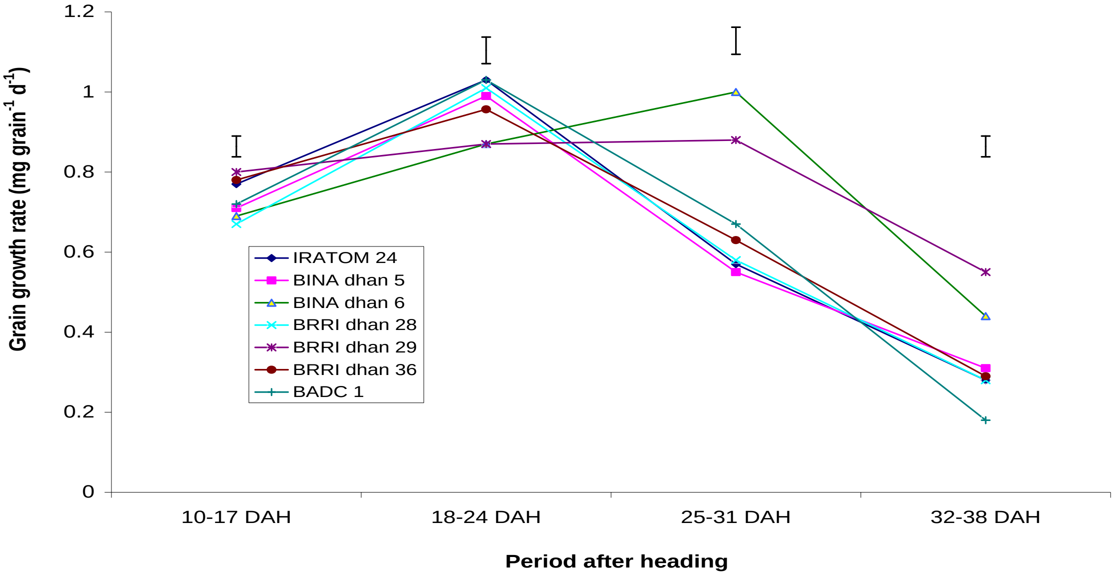


Fig. 9. Grain growth rate in the top rachis grain of the panicle at different periods after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05. DAH = Days after heading

4.2.5 Grain growth rate in middle rachis of the panicle

Significant differences in the grain growth rate (GGR) were observed during 10 - 17 days after heading *(DAH)* and 18-24 DAH non significant during 25 - 31 (Appendix VII). Result revealed that in all varieties GGR during period 18 - 24 DAH remained maximum while before or after that than 10 - 17 DAH periods (Fig.10 and Appendix XIV). During the 10 - 17 and 18 - 24 DAH, the highest GGR were 0.85 and 1.09) recorded from BRRI dhan29 which *was* statistically non identical to others and the lowest was found in BRRI dhan36 (0.79 mg grain^{-1} d$^{-1)}$

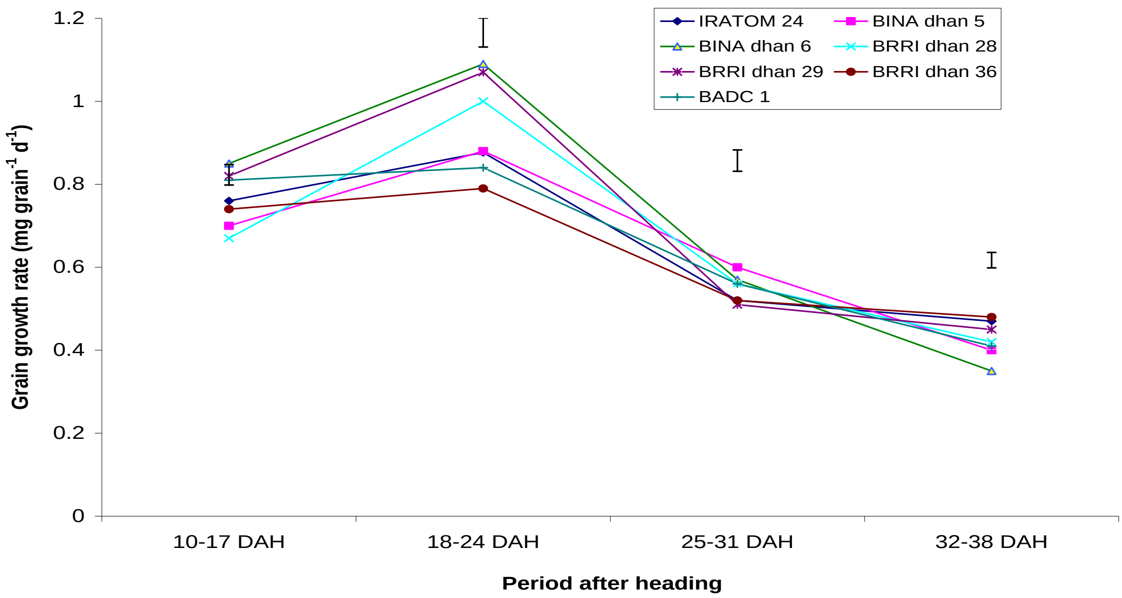


Fig.10. Grain growth rate in the middle rachis grain of the panicle at different periods after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05.DAH = Days after heading.

4.2.6 Grain growth rate in lower rachis of the panicle

Individual grain growth rate (GGR) in lower rachis of the panicle showed significant variation due to variety in all sampling periods (Appendix VIII). During 10 -17 DAH, the maximum GGR (0.80 mg grain^{-1} d^{-1}) was observed in BRRl dhan28 which was statistically similar to IRATOM 24 and minimum GGR (0.50 mg grain^{-1} d^{-1}) was in BRRl dhan36. During 18-24 DAH the highest GGR (1.19 mg grain^{-1} d^{-1}) was found in BRRI dhan29 which was statistically similar to BlNA dhan6 and the lowest GGR (0.69 mg grain^{-1} d^{-1}) was found in BRRI dhan36 which was statistically dissimilar to others. During 25-31 DAH the highest GGR (0.82 mg grain^{-1} d^{-1}) was observed in BRRl dhan36 which was statistically similar to BADCI and the lowest GGR (0.53 mg grain^{-1} d^{-1})was found in IRATOM24 which was statistically identical to BlNA dhan6 .During 32-38 DAH, the maximum GGR (0.37 mg grain^{-1} d^{-1}) was found in BRRl dhan36 which was statistically dissimilar to others and the minimum GGR (0.17 mg grain^{-1} d^{-1}) was observed in BADC1 which was statistically identical to BlNA dhan5, IRATOM24 and BINA dhan6 (Fig. 11 and Appendix XV). The result indicated that the later stage grain growth rate declined. It might be due to gradual declined in photo-assimilates supply from leaves especially the top leaves and also ceased of reserve translocation from leaf sheath and stem.

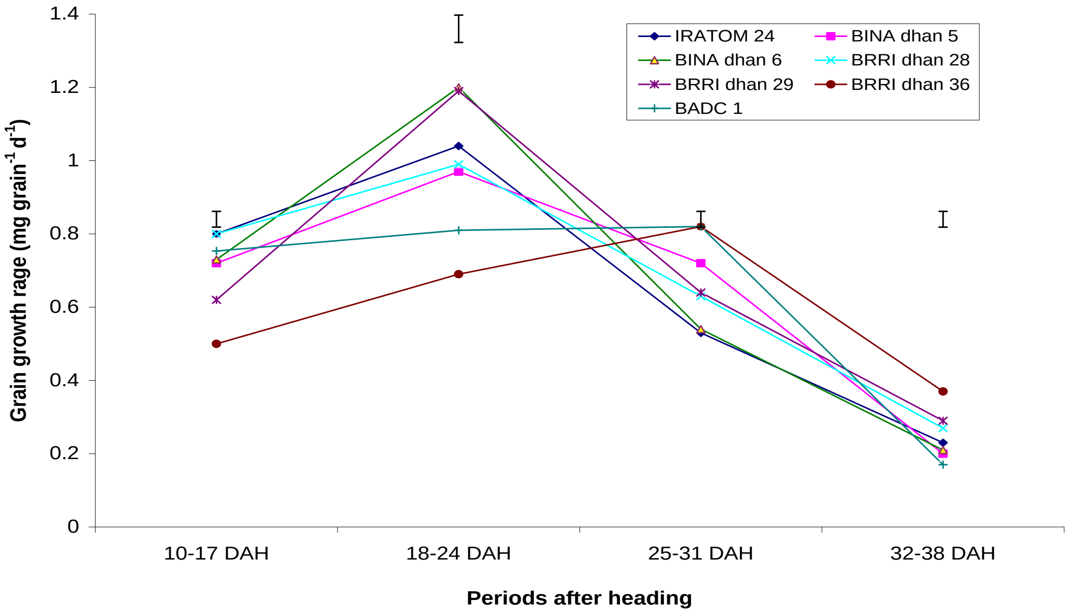


Fig. 11. Grain growth rate in the lower rachis grain of the panicle at different periods after heading of seven modern rice varieties in *boro* season. The vertical bars indicate LSD at 0.05. DAH = Days after heading.

4.3 Phenological stages of individual seven rice varieties stimulated the following yield and yield contributing characters in boro seson

4.3.1 Plant height

The varieties exhibited significant differences in plant height (Appendix IX). At harvest the tallest plant was observed in BADC1 (113.20 cm) which was statistically dissimilar to other varieties. IRATOM24 produced the shortest plant (98.26 cm) which was identical to BRRI dhan28 and BRRI dhan29. The plant height of other varieties was intermediate (Table 1). These differences were mostly due to the genetic variation among the varieties. These results were consistent with Shamshudin *et al*. (1988)

4.3.2 Number of total tillers hill^{-1}

Significant differences in the production of total tillers hill^{-1} were observed in different varieties (Appendix IX). Result presented in (Table 1) showed that the number of total tillers hill^{-1} ranged from 8.24 to 11.43[1]. The highest number of total tillers hill^{-1} was counted in BRRI dhan36 (11.43 hill^{-1}) which was statistically identical to BRRI dhan28, BINA dhan5, BINA dhan6 and BRRI dhan29. The lowest number of total tillers hill^{-1} was observed in IRATOM24 (8.24 hill^{-1}) which was significantly different from other varieties. Variable effect of variety on the number of total tillers hill^{-1} also reported by Hussain *et al*. (1989) who noticed that the number of total tillers hill^{-1} differed among the varieties. The variation in number of total tillers hill^{-1} $^{-}$might be due to varietal character and also the crop environment under which it was grown.

4.3.3 Number of effective tillers hill^{-1}

A rice plant may produce a number of tillers during its early growth period but all of them may not reach to effective i. e. they may not bear panicles. Number of effective tillers hill^{-1} directly affects the grain yield. Varieties differed significantly for this character (Appendix IX). From the Table 1 it was revealed that the highest number of effective tillers hill^{-1} was obtained from BRRI dhan29 (10.33 hill^{-1}) which was significantly identical to BINA dhan6. The lowest number of effective tillers hill^{-1} was found in BRRI dhan36 (7.51 hill^{-1}) which was statistically similar to BADCI (7.56 hill^{-1}) and IRATOM24 (7.72 hill^{-1}). The reasons for differences in producing effective tillers hill^{-1} might be due to the variation in genetic make-up of the variety that might be influenced by heredity. This was consistent with Chowdhury *et al.* (1993) and BRRI (1991) where effective tillers hill^{-1} was reported to be varied with variety.

4.3.4 Panicle length

Length of panicle has an effect on total number of grains per panicle. This character was significantly influenced by the varieties in this experiment (Appendix IX). The panicle length ranged from 22.37--26.05 cm. The highest panicle length was recorded (26.05 cm) from BRRI dhan29 and the lowest panicle length was BRRI dhan36 (22.37 cm) which was statistically dissimilar to others. The rest varieties had intermediate panicle length (Table 1). Idris and Matin (1990) reported that panicle length varied among varieties. So, the present results partially coincide with them. The variation as assessed might be mainly due to genetics characters of the varieties primarily influenced by the heredity. Salam *et al*. (1990) reported that higher grain yield in rice can be achieved from longer panicle length.

4.3.5 Number of total spikelets panicle^{-1}

The results revealed that the number of spikelets panicle^{-1} significantly varied among varieties (Appendix IX). The spikelets number ranged *from* 108.70-155.70 (Table 1). The highest number of total spikelets panicle^{-1} (155.70) was produced by BRRI dhan29 and the lowest number was recorded from BRRI dhan36 (108.70). Differences in number of total spikelets panicle^{-1} due to varieties was also reported by BRRI (1994). Varietal differences regarding the number of total spikelets panicle^{-1} was probably due to their differences in genetic constituents and other biological factors including growth environment of the field and management practices followed during cultivation.

4.3.6 Number of filled grains panicle^{-1}

The results revealed that the number of filled grains panicle^{-1} was significantly influenced by the variety (Appendix IX). It was found that BINA dhan6 produced significantly the maximum number of grains panicle^{-1} (135.10) and it was similar to BRRI dhan29 (134.80). BADC1 produced the lowest grains panicle^{-1} (98.29) which was statistically dissimilar to others (Table1) Kamal *et al.* (1988) reported that variable number of filled grains panicle^{-1} among the varieties. Varietal variation regarding the number of filled grains panicle^{-1} might be due to their variation in genetic constitutions and also due to variation in photosynthetic assimilate accumulation especially after heading.

4.3.7 Number of unfilled spikelets panicle^{-1}

Varieties differed significantly among themselves in case of number of unfilled spikelets panicle^{-1} (Appendix IX). It ranged from 20.55-33.47 panicle^{-1} **.** It was found that the BRRI dhan36 produced the highest number of unfilled spikelets panicle^{-1} (33.47) which was statistically dissimilar to others (Table 1). BINA dhan6 produced the minimum number of unfilled spikelets panicle^{-1} (20.55). Chowdhuray *et al.* (1993) and BINA (1993) reported differences in number of sterile spikelets due to varietal differences. This variation might be due to genetic characteristics of the varieties.

4.3.8 1000-grain weight

Individual grain weight of a variety of rice indicates its grain size and fineness of the quality. From the analysis of variance it was observed that 1000-grain weight was significantly influenced by variety (Appendix IX). The results showed that the maximum weight of 1000-grain (24.33 g) was obtained in BRRI dhan29 which indicated its larger grain size. The minimum weight of 1000-grain (17.58 g) was obtained from BRRI dhan36 and this indicated for its smaller grain size and slender fine grain and the 1000-grain weight of other varieties were intermediate (Table 1). The variation in 1000-grain weight might be due to differences of length and breath of the grains that were partly controlled by genetic makeup of the variety under study. Chowdhury *et al.* (1993) also reported similar view. Further Chowdhury and Gosh (1978) stated that 1000-grain weight highly varied due to variety ranged from 9.00 g to 23.00 g fine and scented rice varieties.

Table 1. Data on plant height, number of total tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of total spikelets panicle^{-1}, number of grains panicle^{-1}, number of unfilled spikelets panicle^{-1}, 1000 grain weight, biological yield and harvest index of seven modern rice varieties in boro season

Variety	Plant height at maturity stage (cm)	No. of total tillers hill^{-1} at maturity stage	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of total spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled spikelets panicle^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
IRATOM24	98.26 c	8.240 c	7.727 c	24.78 ab	133.5 b	102.6 cd	30.84 b	18.69 cd	13.02 bcd	43.70 bc
BINA dhan5	105.4 abc	11.33 a	9.430 ab	25.29 ab	149.7 a	127.4 b	22.35 d	21.75 b	13.82 bc	48.63 a
BINA dhan6	108.9 ab	10.59 a	9.870 a	25.69 ab	155.7 a	135.1 a	20.55 d	22.10 b	14.22 b	48.45 a
BRRI dhan28	100.4 c	11.10 a	8.760 b	24.93 ab	134.7 b	108.7 c	26.00 c	20.14 bc	12.84 bcd	45.33 b
BRRI dhan29	98.67 c	10.79 a	10.33 a	26.05 a	155.7 a	134.8 a	20.92 d	24.33 a	16.41 a	45.65 b
BRRI dhan36	103.3 bc	11.43 a	7.510 c	22.37 c	108.7 c	75.26 e	33.47 a	17.58 d	12.46 cd	41.17 c
BADCI	113.2 a	9.670 b	7.560 c	24.33 b	128.8 b	98.29 d	30.46 b	18.50 cd	12.35 d	44.13 b
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
$S_{\bar{x}}$	2.44	0.285	0.305	0.483	4.27	2.29	0.723	0.640	0.435	0.877
CV (%)	4.07	4.74	6.04	3.38	5.36	3.56	4.76	5.42	5.55	3.36

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

4.3.9 Grain yield

Varieties differed significantly for grain yield in the present study (Appendix IX). The grain yield of varieties ranged from 5.13-7.49 t ha^{-1}. It was found that the highest grain yield (7.49 t ha^{-1}) *was* produced by BRRI dhan29 which was statistically similar to BINA dhan6. Not only the number of effective tillers hill^{-1} , length of panicle, number of filled grains panicle^{-1} 1000 grain weight were maximum but also the LAI and TDM were maximum at all the phenological stages which probably caused the highest yield. The lowest grain yield (5.13 t ha^{-}) was observed in BRRI dhan36 which was identical to BADC1 and IRATOM24. (Fig 12 and Appendix XVI). Grain yield is the ultimate objective of rice cultivation. The yield of rice mainly dependent on the yield contributing characters like the number of effective tiller hill^{-1}, number of grains panicle^{-1}; weight of individual grain or thousand grains weight and number of spikelet sterility. Physiological parameters also play an important role on rice yield which was supported by Cui-Jing *et al*. (2000); Chandra and Das (2000) and Reddy *et al.* (1994) they obtained that higher rice yield possible by increasing total dry matter and harvest index. Grain yield differences due to varieties were also reported by Biswas *et al.* (1998); Guowei *et al.*(1998).

4.3.10 Straw yield

There were significant variations among varieties in respect of straw yield (Appendix IX). The highest straw yield (8.92 t ha^{-1}) was recorded in BRRI dhan29 and the lowest straw yield (7.02 t ha^{-1}) in BRRI dhan28 which was statistical similar to others (Fig.12 and Appendix XVI). The reasons for higher straw yield in the variety of BRRI dhan29 was due to its higher plant height and total tillers hill^{-1} i.e. the combined effect of plant height and tiller number and lower straw yield in BRRI dhan28 might be due to lower plant height and total tillers hill. This result was supported by Chandra *et al.* (1992) and Chowdhury *et al.* (1993) who reported difference straw yield among varieties.

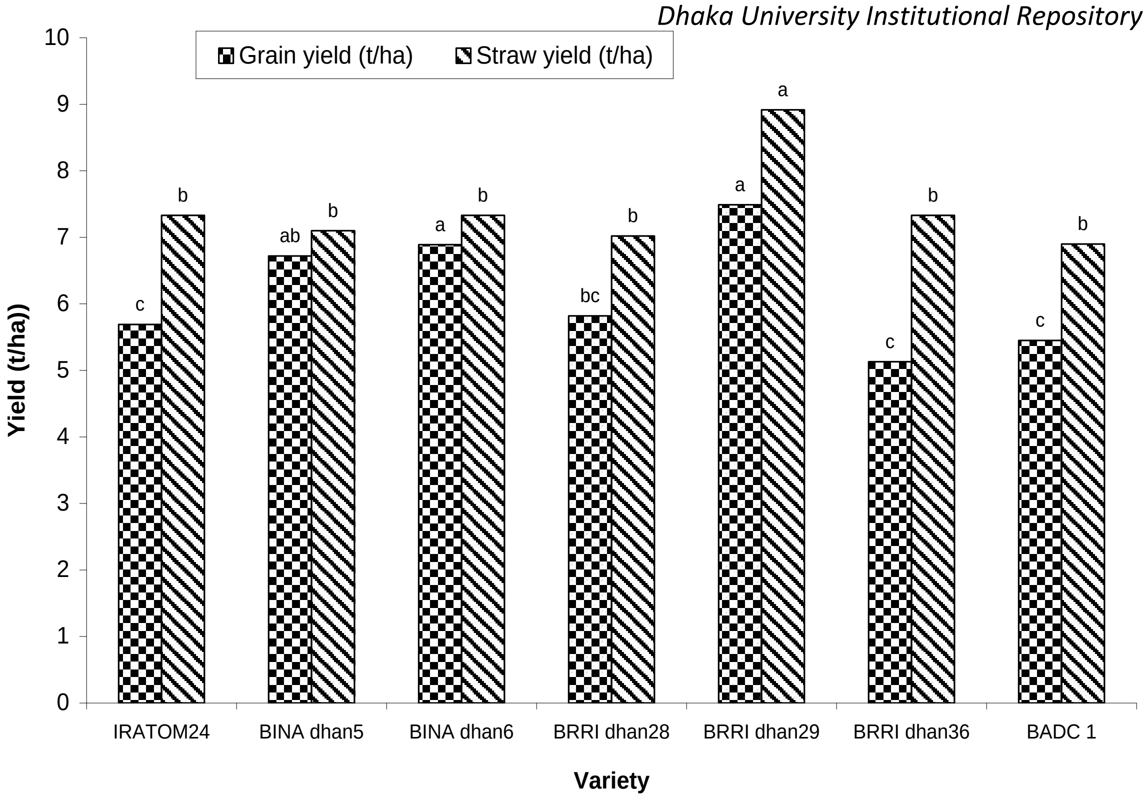


Fig.12. Grain and straw yields of seven modern rice varieties in boro season Similar letters above the bars indicate no significant difference whereas dissimilar letters differ significantly.

4.3.11 Biological yield

The varietal effect on biological yield was significant (Appendix IX). The results showed that the maximum biological yield (16.41 t ha^{-1}) was observed _from the variety BRRI dhan29 which was statistically dissimilar to other varieties. The lowest biological yield (12.35 t ha^{-1}) was found in IRATOM24 and which was statistically identical to BRRI dhan28 (Table 1). The highest grain and straw yield might lead to produce the highest biological yield in BRRI dhan29. This result was agreement with Haque (2002).

4.3.12 Harvest index

Variety exerted a significant effect on harvest index (Appendix IX). It was observed that the highest harvest index (48.63%) was recorded in B1NA dhan5 which was statistically similar to BINA dhan6 (48.45%) and the lowest harvest index was found in BRRI dhan36 (41.17) which was statistically identical to others. Higher grain to straw ratio in BINA dhan5 might be resulted in the maximum harvest index (Table 1). Cui-Jing *et al.* (2000) reported mean harvest index of some Japanese varieties around 43.5% while some Asian bred HYVs to be 48.4%. The result of harvest index thus partially coincides with that report.

4.3.13 Correlation studies between main grain yield contributing characters and grain yield of seven rice varieties in boro season

Yield is a complex characters which is directly associated with various yield contributing characters like number of effective tillers hill^{-1}, number of grains panicle^{-1}, weight of 1000-grain.

4.3.13.1 Grain yield versus effective tillers hill^{-1}, filled grain panicle^{-1} and 1000- grain weight

Results showed that grain yield had significant positive correlation with effective tiller, (r = 0.968**), filled grain (r = 0.947**) and 1000-grain weight (r = 0.987**). These relationships have been shown in (Fig.13, 14 and15). Regression analysis revealed that maximum effective tiller, filled grain, 1000-grain weight resulted in the corresponding maximum in the grain yield of seven modem rice varieties in boro season.

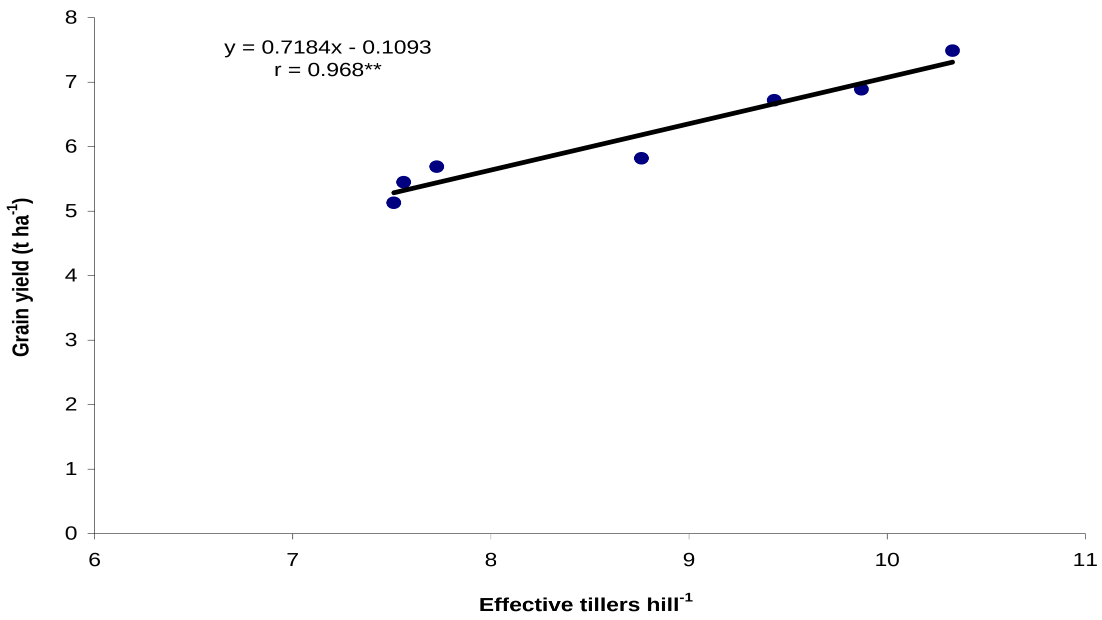


Fig. 13. Relationship between effective tillers hill^{-1} and grain yield

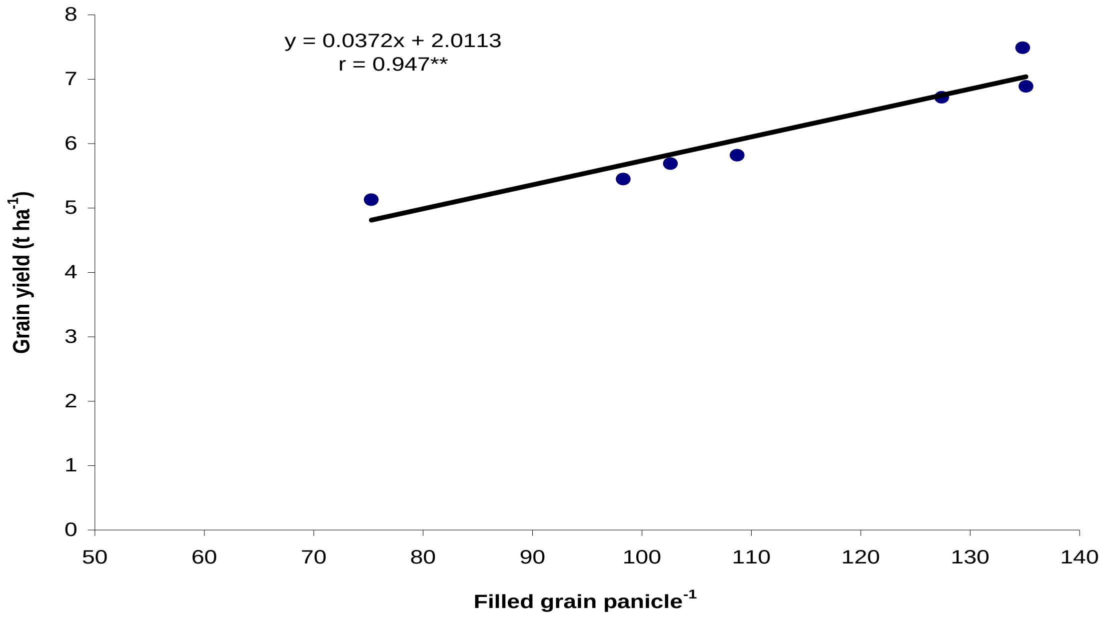


Fig. 14. Relationship between filled grain and grain yield.

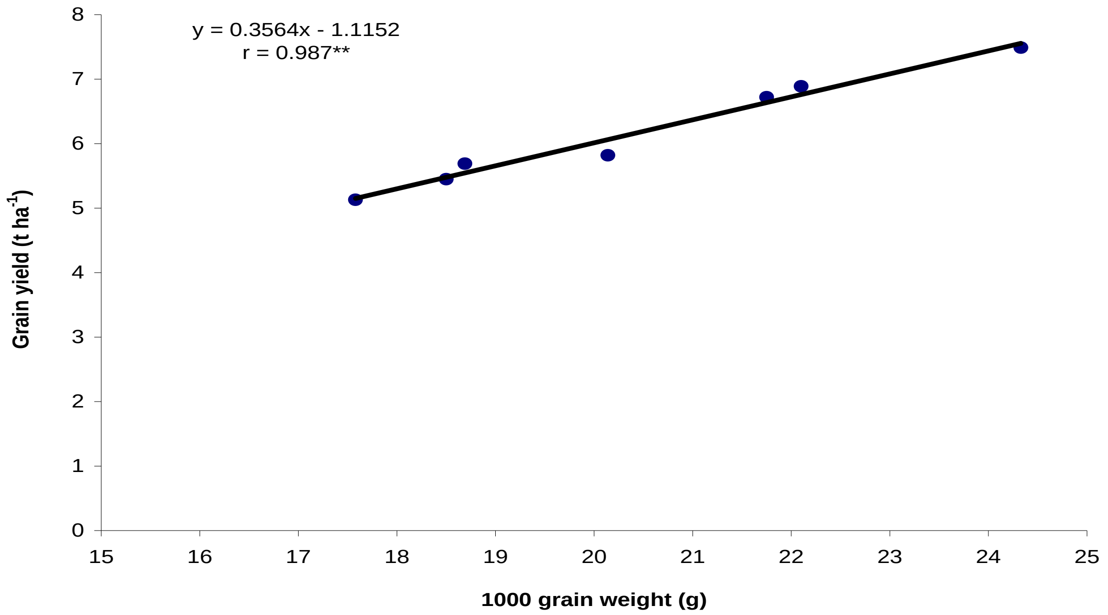


Fig. 15. Relationship between 1000-grain weight and grain yield.

4.4 Biological study of yellow rice stem borer (*Scirpophaga incertulas*)

4.4.1 Egg mass

Egg mass was covered with brownish hairs from the anal tufts of the female. The total number of egg masses, length and width of egg masses were 1.8±0.43 5.4± 0.91 mm and 2.91±0.31 mm (Table 2). Similar results were obtained by Korat and Patel (1988) and Bora *et al*. (1994).

4.4.2 Egg

Eggs were laid within the masses and were white, oval and flat in shape. The mean length and breadth were 0.65 ± 0.03 and 0.38± 0.02 mm respectively, with hatching percentage of 90.19±5.24 (Table 2). Similar result was obtained from Bora *et al*. (1994).

4.4.3 Larva

The larval period lasted for 28.2 ± 0.60 days (Table 4). The first instar larva was yellowish green with dark head and was non-gregarious in feeding habit. Second, third and fourth instar larva were creamy white with black head. Whereas, last instar (fifth instar) was dirty white in colour with length of 19.80 ± 1.21 mm (Table 3).The observations on different instar size and duration are presented in table 3 & 4. There were five larval instars which lasted for 28.2± 0.6 days and was agreed with the reports of Bora *et al*.(1994), but larval duration and body size differed, which may be attributed to the differences in microclimate and crop husbandry practices. In contrast there were six larval instars as per Malhi and Brar (1998) on Basmati 370.

4.4.4 Pupa

The average pupal period was 8.10± 0.44 days (Table 4). However, Malhi and Brar (1998) differed with the present study, according to them the period was 6.90 to 6.96 days during July-August and August- September, respectively. This may be attributed to the changes in climatic conditions, crop variety used for the study and methods of crop establishment. Similar results were reported by Korat and Patel (1988) as 7.74 days at 21°C and 7.22 days at 30°C.

4.4.5 Adult

Similar to pupa several observations on adults were made in the present study as that of other workers. The mean duration of the adult was 68.4 ±2.57 hours for female and 58.50 ± 0.21 hours for male with fecundity of 158.80 ± 39.32 eggs on paddy (Table 4&2) which agreed with the reports of Malhi and Brar (1998). The results of the present study slightly varied from the results of Korat and Patel, (1988).

4.4.6 Total life cycle (Egg to adult emergence)

The average total life cycle of *S. incertulas* was 42.3± 1.23 days (Table 4) which was in agreement with the reports of Malhi and Brar (1998) who reported as 46.35 days, while Korat and Patel (1998) reported as 38.62± 1.60 days during September which differed from the present study due to differences in climatic condition and rice variety used during conducting the experiment.

Table 2. Mean morphological measurements of egg mass, egg, pupa and adult of *Scirpophaga incertulas*

Stage	Mean morphological measurements ± S.D
Egg hatchability (%)	90.19 ± 5.24
No. of eggs hatched on : 6th day	73.3 ± 18.73
No. of eggs hatched on : 7th day	70.5 ± 26.1
Eggs mass length (mm)	5.4 ± 0.91
Egg mass width (mm)	2.91 ± 0.31
Total no. of egg masses laid	1.8 ± 0.43
Fecundity (no. of eggs/female)	158.8 ± 39.32
Egg length (mm)	0.65 ± 0.03
Egg breadth (mm)	0.38 ± 0.02
Pupal Length (mm) Male	11.6 ± 0.14
Pupal Length (mm) Female	12.4 ± 0.18
Pupal Width (mm) Male	2.14 ± 0.02
Pupal Width (mm) Female	1.9 ± 0.35
Wing Expansion (mm) Male	18.6 ± 1.00
Wing Expansion (mm) Female	26.5 ± 0.96
Body Length (mm) Male	8.6 ± 0.58
Body Length (mm) Female	10.9 ± 11.12
Body Width (mm) Male	1.86 ± 0.27
Body Width (mm) Female	2.6 ± 0.03

Data based on 10 observations
Temperature range 15˚c - 25˚c (December - April, 2011)

Table 3. Larval length and head capsule width of *Scirpophaga* incertulas in different instars

Stage	Mean larval length (mm) ± S.D	Mean larval head width (mm) ± S.D
Egg	1.5 ± 0.09	0.20±0.01
Larval instar II	5.2 ± 0.6	0.43±0.04
Larval instar III	9.6 ± 0.26	0.71±0.02
Larval instar IV	14.0 ± 0.61	0.89±0.03
Larval instar V	19.8 ± 1.21	1.15±0.02
Prepupa		12.11 ± 1.30

Data based on 10 observations
Temperature range 15˚c - 25˚c (December – April, 2011

Table 4. Duration of different life stages of *Scirpophaga incertulas*

Stage	**Mean duration of different stages (in days) ± S.D. of stem borer**
Eggs	6.0 ± 0.50
Larval instar I	5.1 ± 0.22
Larval instar II	4.0 ± 0.18
Larval instar III	4.8 ± 0.53
Larval instar IV	4.6 ± 0.62
Larval instar V	6.5±0.33
Prepupa	1.1 ± 0.26
Total larval period	28.2 ± 0.60
Pupa	8.1 ± 0.44
Total life cycle (days)	42.3 ± 1.23
Adult male duration (h)	58.5 ± 0.21
Adult female duration (h)	68.4 ± 2.57

Data based on 10 observations
Temperature range 15˚c - 25˚c (December – April, 2011

4.5 Coincidence of two biotic aspects (plant -*Oryza sativa* and insect- *Scirophophaga incertulas*)

4.5.1 Duration of different phenological stages of seven rice varieties in boro season

The duration of different phenological stages have been presented on table 5 and appendix XVII.The range for seedling stage, vegetative stage, pre reproductive stage, reproductive stage, post reproductive stage and total life cycle were 29.25 (BRRI dhan36)-33.22 (BRRI dhan28) days, 12.33 (IRATOM24) --17.51(BRRIdhan28) days, 14.41 (IRATOM24)- 23.12(BRRIdhan28) days, 15.66 (IRATOM24)-24.37 (BRRI dhan36) days , 16.57(IRATOM24)-22.17(BRRI dhan28) days and 89.59(IRATOM24)-120.4 (BRRI dhan28) days respectively. It was observed that the highest life duration was in BRRI dhan28 which was statistically dissimilar to other varieties and the lowest life duration was in IRATOM24. The life duration for remaining varieties was statistically similar.

Normally the farmers of Bangladesh, started the boro rice cultivation in between the 2^{nd} to 3^{rd} week of January that is the mid-January. For mid-January transplanting time, the seedling started to initiate the tiller from 3^{rd} week of February and continued up to last week of same month. The lengths for duration of month of seedling stage and vegetative stage were mid-January to mid-February and mid-February to last week of February. The length for early reproductive stage, reproductive stage and post reproductive stage of rice varieties were 1^{st} week of March to 3^{rd} week of March, 4^{th} week of March to 2^{nd} week of April and 2^{nd} week of April to last week of April respectively (Fig. 16). .

4.5.2 Duration of different life stages of YSB *(S. incertulas)*

The duration of different life stages of YSB (*S. incertulas*) have been presented in table 4. It was found that the duration of egg to larva, larva to pupa, and pupa to adult and total life cycle were 6. ±0.5 days, 28.2. ± 0.60 days 8.1± 0.44 days and 42.3±1.25 days respectively. Adult male and female duration were 58.5 ±0.21 and 68.4±2.57 hours.

4.5.3 Adult YSB *(S. incertulas)* arrival time in boro season

It was observed that the adult YSB always appeared maximum at 4^{th} week of February in all varieties and no adults were found at 1^{st} week of February (Table 6 and appendix XVIII) .The range for adult abundance at 2^{nd}, 3^{rd} ,4^{th} week of February and 1^{st} week of March were1.00 (BADC1) - 2.23(BINAdhan6), 1.97 (BADC1) - 3.17 (IRATOM24), 7.66 (BADC1) - 18.57 (BINA dhan6) and 0.13 (IRATOM24) - 0.88 (BINA dhan6) respectively (Table 6) .The highest adult appeared in BINA dhan 6 and lowest was in BADC1 during conducting the experiment . This variation of appearing of adult YSB within 15 days might be mainly due to the change of phenological characters of the rice varieties primarily influenced by the YSB and others biotic and a biotic factors involved during conducting the experiment. The variation of abundance of adult YSB in different rice varieties might be due to the genetic characters of the varieties influenced by the YSB. The present investigations were partially agreed with IRRI (1964 and 1972). The larvae which fed on resistant varieties suffered high mortality and were smaller than those fed on susceptible varieties.

4.5.4 Coincidence of the phenological stages of rice and the life stages of YSB *(S. incertulas)*

Coincidence of phenological stages between the host plant and the life stages of insect pest occur very often in nature (Bashar, 2004; Bashar *et al.*, 2006; Bashar, 2013). Synchronizatin of coincidences happens in many phytophagus insects rather than the stem borers are available in the nature. In each case, the coincidences are characteristic species of the insects and also in the different relation with respective plant's phenology (Bashar, 2010 a, b; Bashar, 2012). By consulting the evidences, we have started the present investigation. The result is described below.

Adult YSB arrived and laid eggs at vegetative stage of rice and eggs changed into larvae at the same phenological stage of rice varieties for mid-January transplanting time in boro season. Larva changed into pupa and pupa changed into adult at reproductive stage and post reproductive stage of rice varieties for same transplanting date (Fig.16). After harvesting of the rice varieties, the newly emerged adult eggs were remained in the stubble of paddy fields. This coincidence of two biotic aspects (rice varieties and YSB) continued among the distinct phenological stage of rice and the specific life stage of YSB *(S. incertulas*) in three rice growing seasons (aus, aman and boro) in Bangladesh throughout the year (Fig.17). The present results were consistent with Prakasha Rao (1972) who noted that the attack of *S. incertulas* active tillering stage followed by that at just flowering was more preferred for oviposition.The damage to summer crop was serious, at autumn crop comparatively low but in winter crop it was wide spread (Banerjee and Pramanik,1967). Fewer larvae survived and emerged on younger rice plant. Survival increased with plant age up to 30 and 40 days after sowing, then declined progressively on plant aged 46 and 52 days (Viajante and Saxena, 1988). Parwez *et al*. (2005, 2006) observed that the critical infestation of the stem borers occurred during vegetative and panicle initiation stage of boro rice.

Table 5. Duration of different phenologicla stages of seven rice varieties in boro season

Variety	Duration of different phenological stages (Days)					
	Seedling stage	Vegetative stage	Early reproductive	Reproductive	Post-reproductive	Total life duration
IRATOM24	30.62 bcd	12.33 c	14.41 c	15.66 c	16.57 c	89.59 c
BINA dhan5	32.37ab	15.44 b	20.13 b	19.84 b	20.38 ab	108.2 b
BINA dhan6	31.84abc	17.12 a	21.19 b	20.55 b	19.92 b	110.6 b
BRRI dhan28	33.22a	17.51 a	23.12 a	24.37 a	22.17 a	120.4 a
BRRI dhan29	30.12 cd	15.17 b	20.21 b	20.23 b	20.25 ab	106.0 b
BRRI dhan36	29.25 d	17.49 a	20.17 b	21.45 b	19.27 b	107.6 b
BADCI	30.31 bcd	16.43 ab	19.81 b	20.11 b	21.22 ab	107.9 b
Level of significance	**	**	**	**	**	**
$S_{\bar{x}}$	0.635	0.520	0.536	0.531	0.658	2.70
CV (%)	3.54	5.66	4.67	4.52	5.72	3.35

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 6. Adult yellow rice stem borer (*Scirpophaga incertulas*) arrival time in boro season

Variety	Number of adult of *S.incertulas* (Week of month of February)				Number of adult of *S.incertulas* (Week of month of March)
	1st	2nd	3rd	4th	1st week
IRATOM24	-	2.010 bcd	3.170 a	12.13 b	0.1300 f
BINA dhan5	-	1.970 cd	2.550 c	11.69 b	0.5700 c
BINA dhan6	-	2.230 a	2.880 b	18.57 a	0.8800 a
BRRI dhan28	-	2.110 ab	2.910 b	13.23 b	0.1400 f
BRRI dhan29	-	1.910 d	2.570 c	8.130 c	0.6600 b
BRRI dhan36	-	2.050 bc	2.440 c	9.280 c	0.3300 e
BADC1	-	1.000 e	1.970 d	7.660 c	0.4200 d
Level of significance	-	**	**	**	**
$S_{\bar{x}}$	-	0.041	0.052	0.506	0.018
CV (%)	-	3.83	3.33	7.60	5.77

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

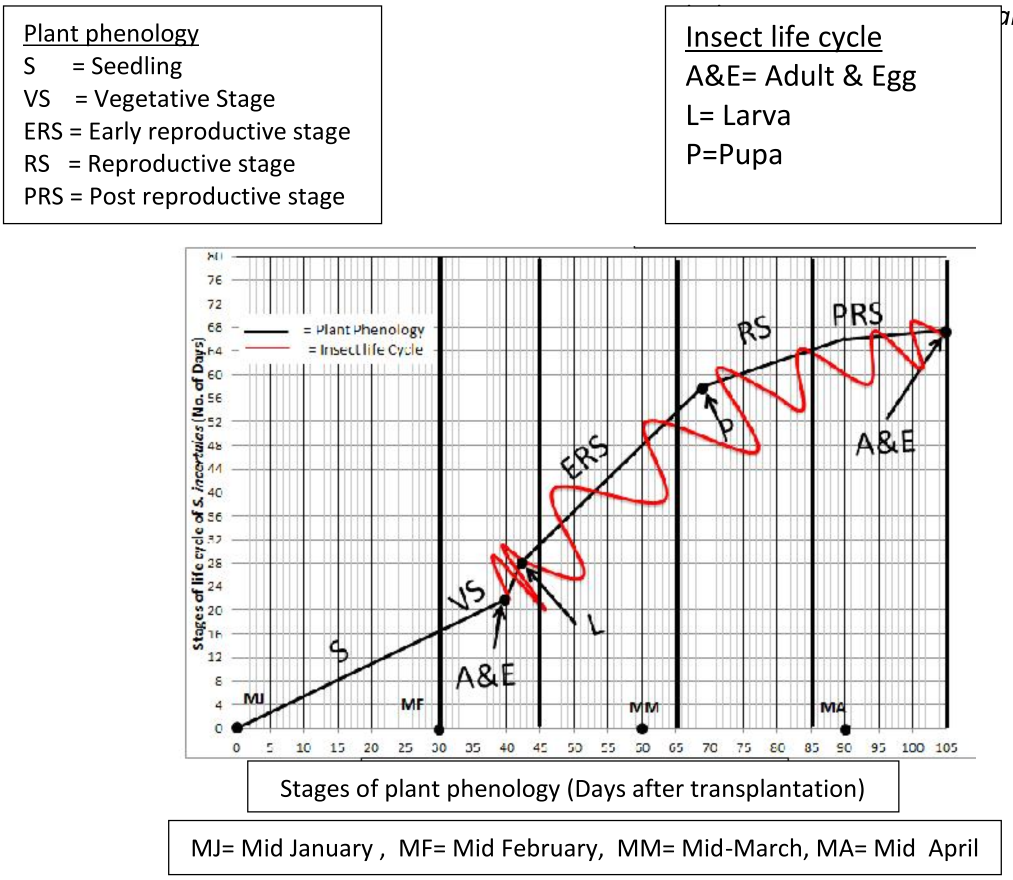
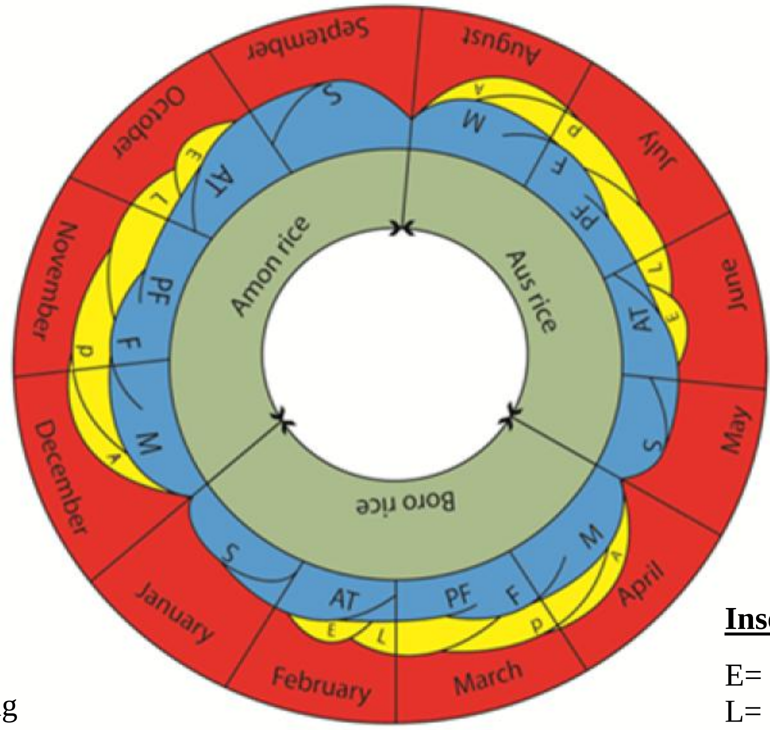


Fig. 16. Coincidence of phenological stages of plant (*Oryza sativa)* and the life stages of insect (*Scirpophaga incertulas*) (2014)



Plant phenology

S= Seedling
AT= Active tillering
PF= Pre Flowering
F= Flowering
M= Maturity

Insect life cycle

E= Egg
L= Larva
P= Pupa
A= Adult

Fig. 17. Coincidence of life cycle of yellow rice stem borer (*Scirpophaga incertulas*) with Aus, Aman & Boro rice (2014)

4.6 Identification of the plant morphological characters influencing infestation of yellow rice stem borer (*Scirpophaga incertulas*)

4.6.1 No. of leaf per tiller

Leaf number varied significantly among the varieties (Table 7 and Appendix XIX). The highest number of leaf was recorded in the variety BADC 1 (4.28) which was found statistically non identical to others. The lowest number of leaf was found in the variety IRATOM 24 (3.68).

4.6.2 Length of flag leaf

Flag leaf length varied significantly among the varieties (Table 7 and Appendix XIX). Longest flag leaf length was observed in the variety BRRI dhan 36 (33.15cm) which was statistically dissimilar to others. Lowest flag leaf length was in the variety BRRI dhan 29 (21.11 cm), which was similar to BADC 1 (21.45 cm).

4.6.3 Width of flag leaf

Flag leaf width varied significantly among the varieties (Table 7 and Appendix XIX). Highest width of flag leaf was observed in the variety BINA dhan 6 (14.36 mm) which was significantly different from others. Lowest width of flag leaf was observed in the variety BINA dhan 5 (11.25 mm).

4.6.4 Length of 2nd leaf

Length of 2nd leaf of different rice varieties range from 33.15cm – 44.25 cm. Length of 2nd leaf varied significantly among the varieties (Table 7 and Appendix XIX). BINA dhan 6 was the longest leaf bearing variety, its length bearing statistically identical to BADC 1 and IRATOM 24.

4.6.5 Width of 2nd leaf

Width of 2nd leaf ranged from 7.15mm - 10.87mm (Table 7 and Appendix XIX). Highest width of 2nd leaf was observed in BRRI dhan 29 (10.87mm) and lowest was in IRATOM 24 (7.15 mm). Width of 2nd leaf found in BINA dhan 6 (9.97 mm) which was statistically similar to BINA dhan 5 (10.15 mm) and BRRI dhan 28 (10.55 mm).

4.6.6 No. of leaf hairs per square cm

Number of leaf hairs per square cm of different rice varieties has been presented in table7. Leaf hairs number range from 7.87 (BINA dhan 5) to 162.58 (BRRI dhan 36). Number of leaf hairs varied significantly among the varieties (Appendix XIX).

4.6.7 Life duration (days) of seven rice varieties

Life duration was all most same in all varieties except IRATOM 24 (Table 7 and Appendix XIX). The range for life duration was 121.14 days (IRATOM 24) to 154.91 days (BRRI dhan 28).

4.6.8 Percentage of YSB (*S. incertulas*) infestation

The highest percentage of YSB infestation was found in BINA dhan 5 which was statistically dissimilar to others and lowest was in BRRI dhan 28 (Table 7 and Appendix XIX).

Table 7. Average plant character values and yellow rice stem borer (YSB) infestation of seven selected rice varieties of different age and session resistant and susceptible to yellow rice stem borer in boro season

Variety	No. of leaf	Length of flag leaf (cm)	Width of flag leaf (mm)	Length of 2nd leaf (cm)	Width of 2nd leaf (mm)	No. of leaf hair (sq. cm)	Life duration (days)	% YSB infestation
IRATOM 24	3.68 d	30.33 b	7.35 d	40.15 a	7.15 c	118.25 b	121.14 b	5.29 b
BINA dhan 5	3.92bcd	28.44 b	11.25 c	36.15 b	10.15ab	7.87 e	143.57 a	10.19 a
BINA dhan 6	4.20 ab	25.87 c	14.36 a	44.25 a	9.97 ab	78.15 c	145.80 a	5.14 b
BRRI dhan 28	4.00abc	24.36 c	11.82bc	35.87 b	10.55 ab	112.36 b	154.91 a	3.67 c
BRRI dhan 29	4.13 ab	21.11 d	12.87 b	33.15 b	10.87 a	20.15 d	140.33 a	4.70 b
BRRI dhan 36	3.76 cd	33.15 a	12.90 b	37.25 b	9.67 b	162.58 a	143.75 a	5.33 b
BADC 1	4.28 a	21.45 d	11.52 c	41.08 a	8.38 c	15.15de	142.50 a	4.49 bc
Mean	4.00	26.39	11.72	38.27	9.53	73.50	141.71	5.54
SE (±)	0.08	1.71	0.83	1.42	0.50	22.90	3.86	0.80
Level of significance	**	**	**	**	**	**	**	**
CV (%)	3.88	5.14	5.01	6.08	5.63	6.41	5.56	9.16

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

4.6.9 Quantitative relations of plant morphological characters with YSB (*S. incertulas*) infestation

The estimated correlation co-efficients among rice stem borer infestation and seven rice varieties were partitioned into direct and indirect effects and have been presented by path-coefficient analysis in Table 8. The direct effect of number of leaf on YSB infestation was negative (-3.10) but its indirect effect via length of 2nd leaf, width of 2nd leaf, number of leaf hairs and life duration were positive. However, length of flag leaf and width of flag leaf were also negative. Finally the over all negative value was higher than positive value which makes the correlation co-efficient between number of leaf and YSB infestion to be negative. Length of flag leaf had a positive direct effect (1.12) and its indirect effect via number of leaf, width of flag leaf, length of 2nd leaf were positive and via width of 2nd leaf, number of leaf hairs, life duration were negative and negligible.

The direct effects of width of flag leaf on YSB infestation were negative (-0.034). Its indirect effects via length of 2nd leaf, width of 2nd leaf, numbers of leaf hairs, life duration were positive but via number of leaf and length of flag leaf were negative which makes the correlation coefficient between width of flag and YSB negative.

Although the length of 2nd leaf exerted positive direct influence (0.020) on YSB infestation but its indirect effect via number of leaf, width of flag leaf, number of leaf hairs and life duration were negative and makes the correlation co-efficient between length of 2nd leaf and YSB infestation negative.

Width of 2nd leaf had a positive (0.035) direct effect on YSB infestation and overall indirect positive effect was higher than negative effect and finally make the relation positive.

The direct effect of number of leaf hairs on YSB was negative (-1.33), its indirect effect via number of leaf, length of flag leaf, width of flag leaf, length of 2nd leaf were positive but via width of 2nd leaf, life duration were negative and make the relation negative.

Finally the life duration had a positive (0.310) direct effect on YSB infestation but its indirect effect via the number of leaf, length of flag leaf, width of flag leaf and length of 2nd leaf were negative and over all negative value were higher than positive value and make the relation negative.

The present investigations were quite in agreement with those of the previous workers. Their findings were as follows: plants with wider and longer leaves, with wider and longer flag leaves, a large number of tillers per hill appeared more susceptible to stem borers (Van Der Goot, 1925; Okamoto and Abe, 1958; IRRI, 1965; and Israel, 1967). Resistant varieties possessed long, dense hairs and more spicules than susceptible varieties (Israel, 1967).

Table 8. Path coefficient analysis of plant characters influencing the yellow rice stem borer (*Scirpophaga incertulas*)

Characters	Number of leaf/ tiller	Length of flag leaf	Width of flag leaf	Length of 2nd leaf	Width of 2nd leaf	Number of leaf hair	Life duration	YSB infestation
Number of leaf/tiller	**-0.310**	-0.961	-0.021	0.0045	0.012	0.868	0.154	-0.253
Length of flag leaf	0.267	**1.12**	0.010	0.0022	-0.011	-0.925	-0.099	0.360
Width of flag leaf	-0.185	-0.316	**-0.034**	0.0003	0.027	0.155	0.234	-0.119
Length of 2nd leaf	-0.069	0.122	-0.0005	**0.020**	0.019	-0.173	-0.057	-0.139
Width of 2nd leaf	-0.108	-0.339	-0.026	0.0108	**0.035**	0.272	0.242	0.086
Number of leaf hair	0.2009	0.772	0.0039	0.0026	-0.0072	**-1.33**	-0.025	-0.382
Life duration	-0.154	-0.359	-0.026	-0.0038	0.028	0.109	**0.310**	-0.097

Residual effect = 0.0198
Bold figures are the direct effects

4.7 Finding out the factors associated with preference and non-preference for egg laying of yellow rice stem borer (*Scirpophaga incertulas*) on different rice varieties

For egg laying of YSB on different rice varieties in boro season 2014 was varied significantly among the varieties. Observation made on number of egg masses deposited, length and width of egg masses, preferential side for oviposition and location of egg masses of YSB on rice leaf in boro season were presented in Table 9 . The mean number of egg masses deposited by YSB (*S. incertulas*) in two boro seasons found a partially differences. In the year 2013 highest number of egg masses was recorded in BRRI dhan 36 which was significantly differ from that of other varieties. The lowest number of egg masses was observed in BADC1.On the other hand in the year 2014, the ranged for egg masses was 1.00-2.06, highest was in BINA dhan6 which was statistically similar to BINA dhan5 and the lowest was in BADC1. It was observed that the least number of egg masses was in BADC1in both the year 2013 and 2014. In 2014 more number of egg masses was found than in 2013 in all varieties except BRRI dhan36.The length and width varied significantly among the varieties. Highest length of egg masses was recorded on IRATOM24 and with the lowest length on BADC1 and statistically similar length was in BINA dhan5, BINA dhan6, BRRI dhan28 and BRRI dhan 36. As regards the preferential side, the dorsal side of leaf was preferred more by the YSB to lay eggs than the vental side with the exception of BRRI dhan 28 (Table 9 and appendix XX).

There was no egg deposition on vental side in the varieties of BINA dhan6, BRRI dha36 and BADC1. Regarding the location of egg masses on the rice leaf, the middle portion was preferred more for egg laying than basal and apical portions. Highest number of egg masses was deposited on basal portion in BRRI dhan 28, on middle portion in BINA dhan 6 and on apical portion in IRATOM24. There was no egg deposition on apical portion in BRRI dhan28, BRRI dhan29, BRRI dhan36 and BADC1.

The present investigation was almost in the same line with those of the previous workers and confirm to the findings of several workers. Their findings were as follows: YSB moths preferred laying more eggs on the dorsal side followed by vental side and leaf sheath under caged condition. Middle portion of leaf was more preferred by the moth than the basal and apical portion and the egg masses covered more area in the susceptible variety (Kojima *et al*., 1955; Prakasa Rao, 1972; Padhi and Chatterji, 1984; Islam and Catling, 1991). Borer preferred glabrous surface of the leaf more than the hairy ones (Lukefahr *et al*., 1965; Pathak, 1971; Pathak *et al*., 1971). Resistant variety in general was less preferred by moth for oviposition than susceptible varieties (Panda *et al.*, 1975; Pathak, 1967; 1969 b; Pathak *et al*., 1971; Manwan and Vega, 1975; Prakasa Rao, 1983b).

Table.9 Length and width of egg masses, oviposition preference, preferencial side for oviposition and location of egg masses of *Scirpophaga incertulas* on rice leaf (EBBL, boro season: 2013-2014)

Variety	Number of egg mass		Length of egg masses	Width of egg masses	Preferential side			Middle	Apical
	2013	2014			Dorsal	Ventral	Basal		
			2013						
IRATOM 24	1.01 d	1.61 b	5.33 a	3.33 a	0.43 bc	0.12 b	0.150 c	0.160 d	0.480a
BINA dhan 5	1.04 d	2.00 a	4.04 c	2.85 b	0.45 b	0.25 a	0.170 c	0.510 b	0.350b
BINA dhan 6	1.71 b	2.06 a	4.00 c	2.90 b	0.69 a	0.00 c	0.00 d	0.700 a	0.330b
BRRI dhan 28	1.29 c	1.40 c	3.93 c	2.87 b	0.20 e	0.21 a	0.530 a	0.160 d	0.00 c
BRRI dhan 29	1.03 d	1.33 c	5.01 b	3.37 a	0.33 cd	0.10 b	0.330 b	0.350 c	0.00 c
BRRI dhan 36	2.60 a	1.05 d	4.17 c	3.18 a	0.33 bcd	0.00 c	0.170 c	0.330 c	0.00 c
BADC 1	0.35 e	1.00 d	2.90 d	2.00 c	0.30 de	0.00 c	0.150 c	0.310 c	0.00c
Mean	1.29	1.49	4.20	2.93	0.390	0.097	0.214	0.360	0.166
SE (±)	0.267	0.159	0.299	0.175	0.059	0.039	0.064	0.073	0.080
Level of significance	**	**	**	**	**	**	**	**	**
CV (%)	6.16	3.96	3.21	4.39	16.31	35.30	25.01	13.03	22.88

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

4.8 Evaluation of the presence of antibiosis as expressed from the survival and growth rate of yellow rice stem borer (*Scirpophaga incertulas*) larvae and pupae inhabiting resistant and susceptible rice varieties

The growth of the larvae and pupae were determined by their length, width and weight on different rice varieties. The survival percentage of the larvae and the length, width and weight of larvae and pupae on seven rice varieties varied significantly (Table 10 and appendix XXI).The length, width and weight of larvae and pupae and survival percentage of larvae were lower on the resistant varieties as compared to those on susceptible varieties. The range of larval length, width, weight and survival percentage were 10.10 (IRATOM24) - 14.20 (BRRI dhan 29) cm, 1.07 (BINA dhan6)-2.00 (BINA dhan5) mm, 15.75 (IRATOM24)-24.01(BRRI dhan29) mg, 45.33 (IRATOM24)-72.67 (BINA dhan5) % respectively. On the other hand the range for length, width and weight of pupa were 9.27 (IRATOM24)-14.17 (BINA dhan6) cm, 2.18 (IRATOM24)-2.93 (BINA dhan5) mm and 20.67 (IRATOM24)-26.95 (BRRI dhan28) mg respectively. The highest % of infestation of YSB was observed in BINA dhan6 and the lowest was in BADC1.

There was a positive correlation between % YSB infestation and larval length (0.033), larval weight (0.153), larval survival (0.837), pupal length (0.751), pupal width (0.558) and pupal weight (0.604). Only larval width was negative (-0.032) (Table 11).

The present investigations were quite in conformity with those of the previous workers like (Tsutsui *et al*., 1957; Pathak, 1964; Pathak *et al*., 1971; IRRI, 1964, 1972, 1974, 1978). The varieties tested by these workers for YSB and other species of the stem borers were different from those under present investigations but the effect of resistant varieties on the survival and development of the pest was similar.

Table 10. Mean yellow rice stem borer (*Scirpotationphaga incertulas*) Antibiosis indices on boro rice varieties (EBBL, 2013)

Characters	Larval				Pupal			YSB infestation (%)
	Length (cm)	Width (mm)	Weight (mg)	Survival (%)	Length (cm)	Width (mm)	Weight (mg)	
IRATOM 24	10.10 d	1.60 b	15.75 d	45.33d	9.27d	2.18 d	20.67 e	33.67 e
BINA dhan 5	12.85 ab	2.00 a	20.55 b	72.67 a	12.15 b	2.930 a	22.85 c	48.36 b
BINA dhan 6	11.67bc	1.07 c	17.77c	65.15b	14.17 a	2.47 bc	25.15 b	52.45 a
BRRI dhan 28	13.15ab	1.59 b	20.36b	64.85 b	13.87a	2.90 a	26.95 a	40.58d
BRRI dhan 29	14.20 a	1.97a	24.01a	50.67c	11.20c	2.67ab	22.15cd	39.33d
BRRI dhan 36	10.91cd	1.33 bc	13.33e	65.33b	12.67b	2.75a	24.81b	44.51 c
BADC 1	12.51b	1.25c	16.12d	48.71cd	10.75c	2.29cd	21.26de	29.40 f
Mean	12.20	1.54	18.27	58.96	12.01	2.60	23.40	41.19
SE (±)	0.530	0.134	1.364	3.967	0.661	0.111	0.871	3.042
Level of significance	**	**	**	**	**	**	**	**
CV (%)	6.66	10.43	4.62	3.65	3.79	5.76	3.24	3.98

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 11. Correlation matrix between antibiosis indices and yellow rice stem borer (*Scirpophaga incertulas*) infestation rate (boro rice)

Characters	Larval width (mm)	Larval weight (mg)	Larval survival (%)	Pupal length (mm)	Pupal width (mm)	Pupal weight (mg)	YSB infestation (%)
Larval length(mm)	0.508	0.864*	0.135	0.245	0.528	0.145	0.033
Larval width(mm)		0.700	0.042	-0.308	0.468	-0.256	-0.032
Larval weight(mg)			0.078	0.128	0.446	0.056	0.153
Larval survival(%)				0.794*	0.800*	0.713	0.837*
Pupal length (mm)					0.620	0.932**	0.751
Pupal width (mm)						0.644	0.558
Pupal weight (mg)							0.604

4.9 Monthly pattern of occurrence of yellow rice stem borer (*Scirpophaga incertulas*) in light trap

From the monthly pattern of occurrence it was found that the YSB occurred in large number during August to November and April to June (Fig. 18 and appendix XXII). In December to February abundance of YSB was observed comparatively very low. However, population of YSB began to increase from March to April and first peak of the year occurred during the month of May. This may be attributed to the change in climatic conditions, crop variety used during study and the methods of crop cultivation.

The result of monthly pattern of occurrence of YSB *(S. incertulas*) in light trap agreed with Alam *et al*. (1972) and Alam and Quraishi (1976) who reported that the large population of YSB *(S. incertulas*) observed from August to middle October as well as from April to July. Similar observation was also reported by Mishra *et al.* (2012) as YSB exhibiting their peak n the month of September. Adiroubane and Raja (2010) reported that the YSB influenced by weather parameters.

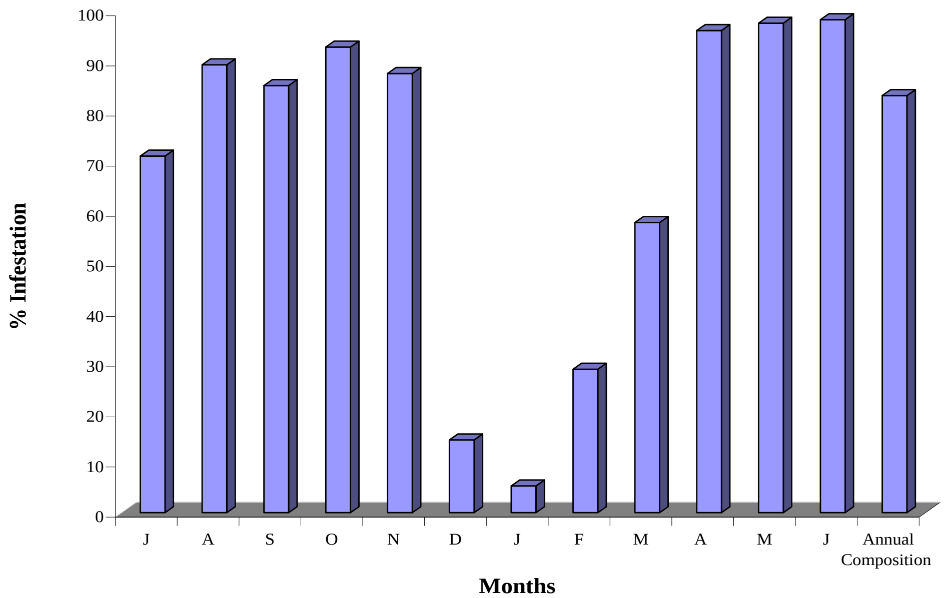


Fig.18. Composition of YSB (*Scirpophaga incertulus*) in monthly moth Populations caught in light trap 2011-2012

4.10 Nature of damages caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenlogical stages of seven rice varieties in boro season (2012-2013)

Infested hills, infested tillers and infested tillers without appearing any symptom showed significant differences in three phonological stages among the varieties (Appendix XXIII – XXIX). It was found that the infested hills as well as infested tillers were maximum at preflowerng stage and minimum were in active tillering stage in all varieties (Table 12-18). On the other hand, infested tiller without appearing any symptom highest was in flowering stage and lowest was in preflowering stage in all varieties.

Though the 'Dead heart' (DH) and 'White head' (WH) formation observed through stem dissection were maximum in preflowering stage in all varieties but in case of direct field count, active tiller stages produced the highest % of 'Dead heart' (DH) and 'White head' (WH) as compare to flowering stage in all varieties.

This result was consistent with Tsutsui *et al*. (1957) who noticed that the % of infestation by the borer species were different at different growth stages of rice. IRRI (1987) reported that fewer 'dead heart' were observed in younger plants than in plants at 34, 40 and 46 days after transplanting. 'Dead heart' count declined sharply at 52 days after transplanting. Israel *et al*. (1965) reported that losses due to rice borer in the earlier stage and heading stage were 21.6% and 26.9% respectively.

Table 12. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in IRATOM24 during 2012-2013 (boro season)

Nature of damages	**Phenological stages**			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	10.97 b	20.25 a	19.37 a	78.72	3.31
Infested tillers	1.67 b	2.33 a	2.20 a	0.367	5.85
IT WAS	0.73	0.67	1.10	0.163	10.95
DH and WH formation	1.00 b	1.61 b	0.63 a	0.735	5.18
b) Direct field counts					
DH and WH formation	0.47 a	-	0.41 b	0.196	15.75

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 13. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BINA dhan5 during 2012-2013 (boro season)

Nature of damages	Phenological stages			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	11.17 c	21.33 a	18.69 b	83.37	3.84
Infested tillers	1.51 c	2.67 a	2.33 b	1.067	3.26
IT WAS	0.70 b	0.60 b	1.18 a	0.288	7.46
DH and WH formation	0.89 b	1.75 a	0.58 c	1.102	6.59
b) Direct field counts					
DH and WH formation	0.41 a	-	0.37 b	0.153	13.32

Means having common letters do not differ significantly at (*) 5% and (**) 1% level (Duncan's New Multiple Range Test).

Table 14. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BINA dhan6 during 2012-2013 (boro season)

Nature of damages	Phenological stages			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	13.05 c	24.10 a	20.28 b	94.48	3.87
Infested tillers	2.01 c	2.89 a	2.42 b	0.582	6.90
IT WAS	0.67 b	0.55 b	1.25 a	0.420	17.34
DH and WH formation	0.81 b	1.59 a	0.67 b	0.737	6.58
b) Direct field counts					
DH and WH formation	0.50 a	-	0.33 b	0.194	20.87

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 15. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan28 during 2012-2013 (boro season)

Nature of damages	Phenological stages			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	12.33 c	21.73 a	19.11 b	70.59	3.82
Infested tillers	1.75 c	2.87 a	2.33 b	0.941	3.41
IT WAS	0.76 b	0.58 c	1.20 a	0.305	7.73
DH and WH formation	1.06 b	1.73 a	0.81 c	0.686	8.54
b) Direct field counts					
DH and WH formation	0.47 a	-	0.39 b	0.190	18.13

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 16. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan29 during 2012-2013 (boro season)

Nature of damages	Phenological stages			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	14.25 c	23.21 a	20.90 b	64.92	3.51
Infested tillers	1.97 c	3.15 a	2.65 b	1.052	3.64
IT WAS	0.80 b	0.65 a	1.33 c	0.383	6.28
DH and WH formation	1.11 b	1.90 a	0.87 c	0.871	7.42
b) Direct field counts					
DH and WH formation	0.50 a	-	0.33 b	0.194	16.30

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 17. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan36 during 2012-2013 (boro season)

Nature of damages	**Phenological stages**			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	10.67 c	21.33 a	18.69 b	92.463	3.30
Infested tillers	1.40 c	2.33 a	2.12 b	0.714	4.18
IT WAS	0.65 b	0.57 b	1.00 a	0.157	6.17
DH and WH formation	0.83 b	1.58 a	0.47 c	0.962	7.61
b) Direct field counts					
DH and WH formation	0.38 a	-	0.33 b	0.128	24.40

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 18. Assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phonological stages in BADC 1 during 2012-2013 (boro season)

Nature of damages	**Phenological stages**			Analysis of variance	
	Active tillering (%)	Preflowering (%)	Flowering (%)	M.S.S	C.V. (%)
a) Stem dissection					
Infested hills	9.37 c	18.67 a	16.90 b	73.162	3.78
Infested tillers	1.47 b	2.16 a	1.99 a	0.388	4.93
IT WAS	0.67 b	0.58 b	0.98 a	0.132	6.77
DH and WH formation	0.94 b	1.37 a	0.52 c	0.542	9.20
b) Direct field counts					
DH and WH formation	0.40 a	-	0.31 b	0.132	21.27

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

4.11 Relative percentage of 'dead heart' (DH) and 'white head' (WH) formation at different phenological stages of seven rice varieties in boro season (2012-2013)

In case of relative percentage of 'dead heart' and 'white head' at active tillering stage the highest percentage was found in BRRI dhan 36 (1.47) and lowest was in BADC 1 (0.45) which was statistically similar to BRRI dhan 28 (Table 19 and appendix XXX). On the other hand at preflowering stage the maximum percentage of 'dead heart' and 'white head' was observed in BINA dhan 5 (2.57) which was identical to BRRI dhan 36 (2.53). Finally at flowering stage the highest percentage of 'dead heart' and 'white head' was observed in BINA dhan 6 (1.60) and lowest was in BADC 1 (0.33) which was similar to BRRI dhan 28 (0.40). Present results were agreed with Israel *et al*., (1965) who reported that losses due to rice borer in the earlier stage and heading stage were 21.6% and 26.9% respectively.

Table 19. Relative percentages of 'Dead heart' (DH) and 'White head '(WH) formation in seven different rice varieties during different phenological stages as computed from weekly stem dissections, boro Season (2012-2013)

Phenological stages	DH and WH %							Analysis of variance	
	IRATOM 24	BINA dhan 5	BINA dhan 6	BRRI dhan 28	BRRI dhan 29	BRRI dhan 36	BADC 1	M.S.S	C.V. (%)
Active tillering	1.39 a	0.77 c	0.95 b	0.50 d	1.00 b	1.47 a	0.45 d	0.490	6.93
Pre-flowering	1.67 b	2.57 a	1.48 bc	1.25 c	1.47 bc	2.53 a	1.33 c	0.932	6.87
Flowering	1.48 b	1.10 c	1.60 a	0.40 e	0.70 d	0.41 e	0.33 e	0.855	6.17

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

4.12 Control measures of yellow rice stem borer (*Scirpophaga incertulas*)

4.12.1 Avoiding the temporal coincidence between the two biotic aspects; the plant (*Oryza sativa*) and the insect (*S. incertulas*) by selecting a suitable time of transplanting of rice varieties in boro season.

4.12.1.1 Number of egg masses of YSB presence at different phenological stages of seven rice varieties at different transplanting time in boro season

The number of egg masses of YSB presence at different phenological stages of seven rice varieties has been presented at table 20, 21 and 22. It was found that the number of egg masses were significantly higher at vegetative stage than other phenological stages of seven rice varieties at three different transplanting time(Appendix XXXI, XXXII and XXXIII). No egg masses were found at reproductive stage and post reproductive stage of seven rice varieties in three different transplanting times. Number of egg masses was always significantly higher at mid January transplanting time than at early and late January transplanting time of each phenological stage of seven rice varieties.

The range for number of egg masses at vegetative stage were 1.57 (BRRI dhan 28) -2.18 (BRRI dhan36), 0.68 (BRRI dhan29)-0.96 (IRATOM24) and 0.81 (BRRI dhan29)-1.115(BRRI dhan36) at mid-January transplanting time, early- January transplanting time and late -January transplanting time respectively. The present investigations were partially agreed with Viajante and Saxena (1988).

4.12.1.2 Finding out the suitable time of interaction between the phenological stages of rice and the life stages of YSB *(S. incertulas)*

It was found that the adult YSB was always highest appeared at last week of February at the vegetative stage of seven rice varieties for mid-January transplanting time as compared to early- January transplanting time and late -January transplanting time in boro season (Table 6) .This strong interaction between the two biotic indicators played a significant role to sustain the each life stage of YSB. Therefore the mid-January transplanting time of rice varieties in boro season made a temporal favorable coincidence between the each life stages of YSB and the different phenological stages of rice varieties.

4.12.1.3 Breaking the temporal coincidence between the phenological stages of rice varieties and the life stages of YSB (S. *ncertulas*) by transplanting the rice varieties in boro season except the mid-January

The vegetative stage for early January transplanting time and late January transplanting time were 1st week to 3rd week of February and 1st week to 2nd week of February respectively. As the adult YSB appeared at the last week of February at vegetative stage of rice , so when the rice varieties were transplanted at early and late January instead of mid January , the vegetative stage of rice varieties not appeared at last week of February (fig.19, 20 1nd 21). There might be less adult arrived as well as less egg laid mainly due to the absence of vegetative stage at the last week of February for early or late January transplanting time instead of mid January transplanting time (Table 5 and 6) . The present investigations were in agreed with the hypothesis of Saxena (1978) who reported that an understanding of insect-plant interaction can be invaluable in development of superior control method with stable level of insect.

Table 20. Number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for mid-January transplanting time in boro season

Variety	Number of egg masses at different phenological stages				
	Seedling stage	Vegetative stage	Early reproductive stage	Reproductive stage	Post-reproductive Stage
IRATOM24	0.707 ab	2.06 a	1.03 a	-	-
BINA dhan5	0.660 b	1.970 ab	0.990 ab	-	-
BINA dhan6	0.740 a	2.23a	1.12 a	-	-
BRRI dhan28	0.520 c	1.57 c	0.790 c	-	-
BRRI dhan29	0.560 c	1.68 bc	0.840 bc	-	-
BRRI dhan36	0.730 a	2.18 a	1.09a	-	-
BADC1	0.700 ab	2.11 a	1.06 a	-	-
Level of significance	**	**	**	-	-
$S_{\bar{x}}$	0.018	0.097	0.052	-	-
CV (%)	5.64	8.45	8.94	-	-

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 21. Number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for early-January transplanting time in boro season

Variety	Number of egg masses at different phenological stages				
	Seedling Stage	Vegetative stage	Early reproductive Stage	Reproductive Stage	Post-reproductive Stage
IRATOM24	0.3300 bc	0.9600 a	0.5133 bc	-	-
BINA dhan5	0.5100 a	0.8800 a	0.6800 a	-	-
BINA dhan6	0.3700 bc	0.7300 c	0.5000 bc	-	-
BRRI dhan28	0.4100 b	0.7600 bc	0.4400 cd	-	-
BRRI dhan29	0.2200 d	0.6800 c	0.3900 d	-	-
BRRI dhan36	0.3133 c	0.8700 ab	0.5700 b	-	-
BADC1	0.4100 b	0.9300 a	0.4900 bcd	-	-
Level of significance	**	**	**	-	-
$S_{\bar{x}}$	0.026	0.037	0.032	-	-
CV (%)	11.70	7.40	11.44	-	-

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Table 22. Number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for late-January transplanting time in boro season

Variety	**Number of egg masses at different phenological stages**				
	Seedling Stage	**Vegetative stage**	Early reproductive Stage	Reproductive Stage	Post-reproductive Stage
IRATOM24	0.5100 b	1.130 a	0.8800 a	-	-
BINA dhan5	0.6600 a	0.9700 ab	0.9100 a	-	-
BINA dhan6	0.4400 b	0.8800 b	0.7700 ab	-	-
BRRI dhan28	0.5100 b	0.9600 ab	0.6700 b	-	-
BRRI dhan29	0.4700 b	0.8100 b	0.6600 b	-	-
BRRI dhan36	0.6200 a	1.150 a	0.6700 b	-	-
BADC1	0.440b	0.9900 ab	0.7900 ab	-	-
Level of significance	**	**	**	-	-
$S_{\bar{x}}$	0.026	0.061	0.045	-	-
CV (%)	8.73	10.58	10.25	-	-

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

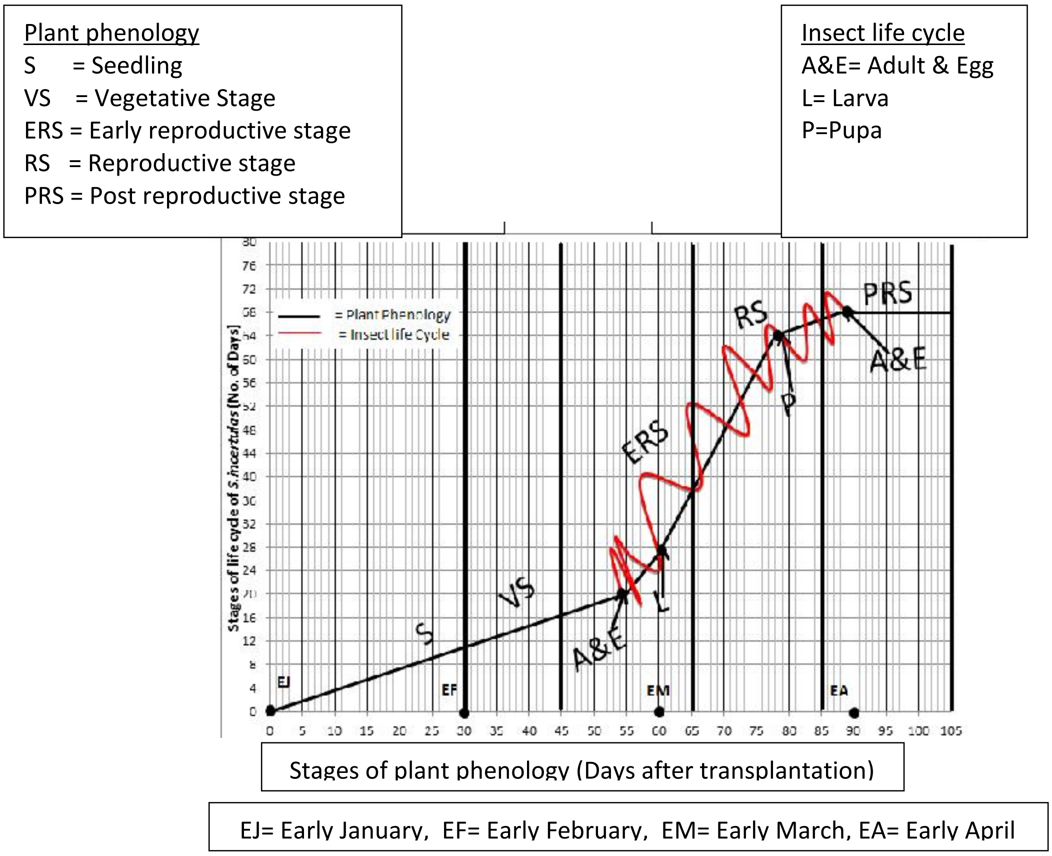


Fig. 19. Coincidence of phenological stages of plant (*Oryza sativa)* and the life stages of insect (*Scirpophaga incertulas*) at Early- January transplanting time

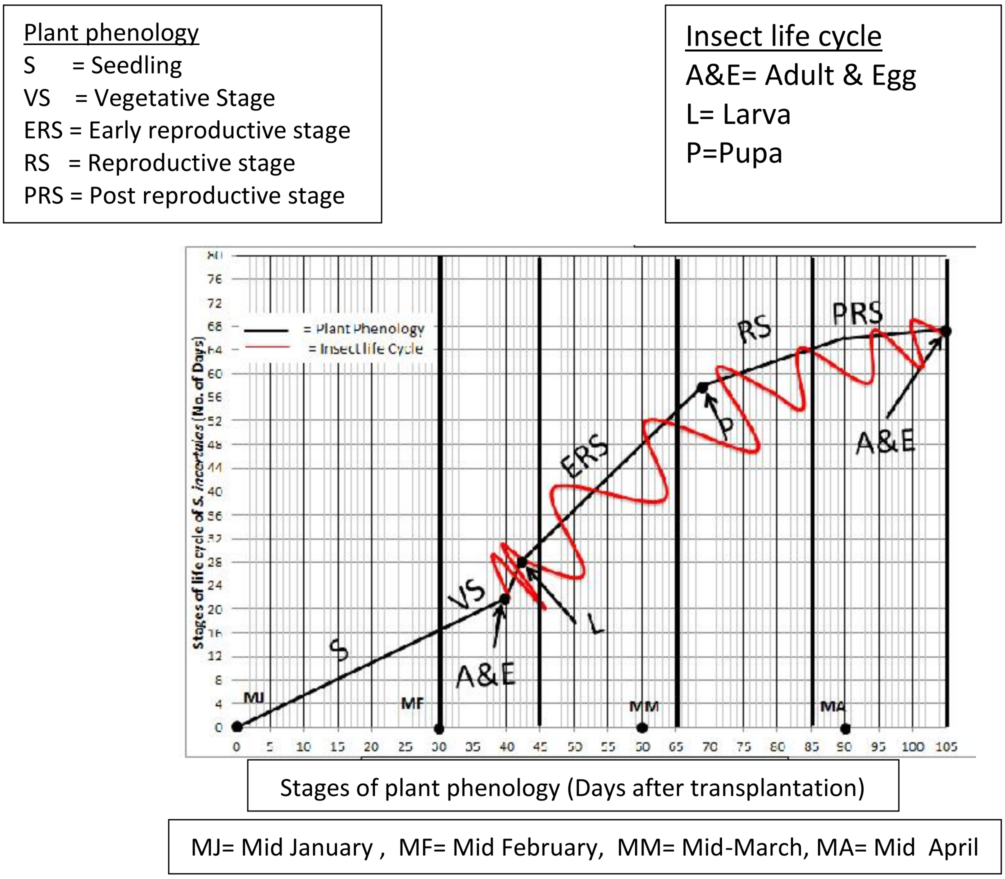


Fig. 20. Coincidence of phenological stages of plant (*Oryza sativa)* and the life stages of insect *Scirpophaga incertulas*) at Mid- January trans planting time

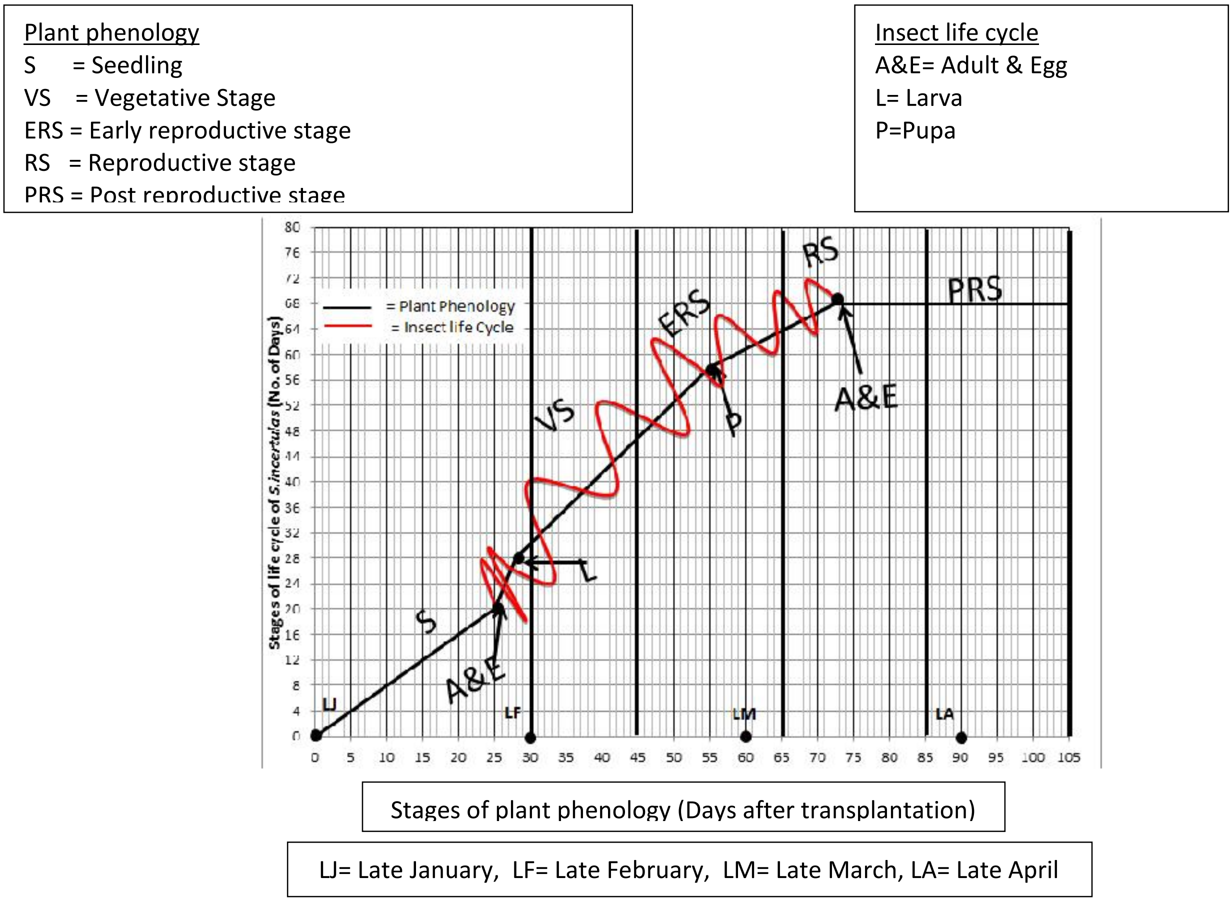


Fig. 21**.** Coincidence of phenological stages of plant (*Oryza sativa)* and the life stages of insect (*Scirpophaga incertulas*) at Late- January transplanting time

4.12.1.4 Percentage of infestation of YSB (*S. incertulas)* at different transplanting time of seven rice varieties in boro season

The percentage of infestation of YSB has been presented at table23. The percentage of infestation of YSB in all rice varieties were always lower at early and late January transplanting time as compared to mid-January transplanting time in boro season . Date of transplanting time played a significant effect on the occurrence of YSB. The percentage of infestation of YSB ranged were 11.98(BADC)-18.62(BINA dhan6) %, 29.40 (BADC1)-52.45(BINA dhan6) % and 15.33(BADC1)-22.22(BINA dhan6) % at early January transplanting time, mid January transplanting time and late January transplanting time in boro season respectively (Appendix XXXIV). The variation of percentage of infestation of YSB as assessed might be mainly due the change of phenological stages of rice varieties in boro season only within 15 days interval .There might be other biotic factors including a biotic factors like temperature, humidity, rainfall, growth environment of the fields and management practices followed during conducting the experiment involved for the variation of percentage of infestation of YSB. The present investigations were in partially agreement with those of Banerjee and Pramanik 1967); Catling and Alam (1977); Kamran and Raros (1968); Pathak (1968); Prakasa Rao *et al*. (1971) and Van Der Goot (1948b) who reported that temperature, humidity, rainfall had marked influence on the incidence of YSB.

Table 23. Percentage of infestation at different transplanting dates of seven rice varieties in boro season

Variety	EJ	MJ	LJ
IRATOM24	12.88 d	33.67 e	15.33 d
BINA dhan5	15.49 bc	48.36 b	20.87 ab
BINA dhan6	18.62 a	52.45 a	16.77 c
BRRI dhan28	16.17 b	40.50 d	19.98 b
BRRI dhan29	15.81 b	39.33 d	17.62 c
BRRI dhan36	14.82 c	44.51 c	18.17 c
BADCI	11.98 d	29.40 f	22.22 a
Level of significance	**	**	**
$S_{\bar{x}}$	0.303	0.909	0.442
CV (%)	3.48	3.83	4.09

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT. EJ= Early January, MJ= Mid- January, LJ= Late January

4.12.1.4 Yield of seven rice varieties in boro season at different transplanting dates

Though the yield is a complex characters but it is also associated with the time of transplantation. Early- January transplanting time produced the highest yield ton ha^{-1} as compared to late- January transplanting time and mid-January transplanting time in five verities out of seven varieties in boro season. Lowest yield was observed at mid-January transplanting time as compared to early or late January transplanting time in four varieties out of seven varieties. Results indicated that the range of yield were 5.1-7.49, 4.10-5.99 and 4.01-6.74 ton ha^{-1} respectively in early January, mid-January and late January transplanting time (Fig. 22 and appendix XXXV - XXXVI). Varieties differ significantly for grain yield in three different transplanting times in boro season. Highest grain yield was produced by BRRI dhan29 in three different transplanting times. Though the grain yield depends on the yield contributing characters but the insect infestation also play an important role for reducing the yield of rice. The present investigations were in conformity with those of the previous workers; yield loss is found positively correlated with dead heart and white head infestation of the crop (Rahman *et al*., 2004).

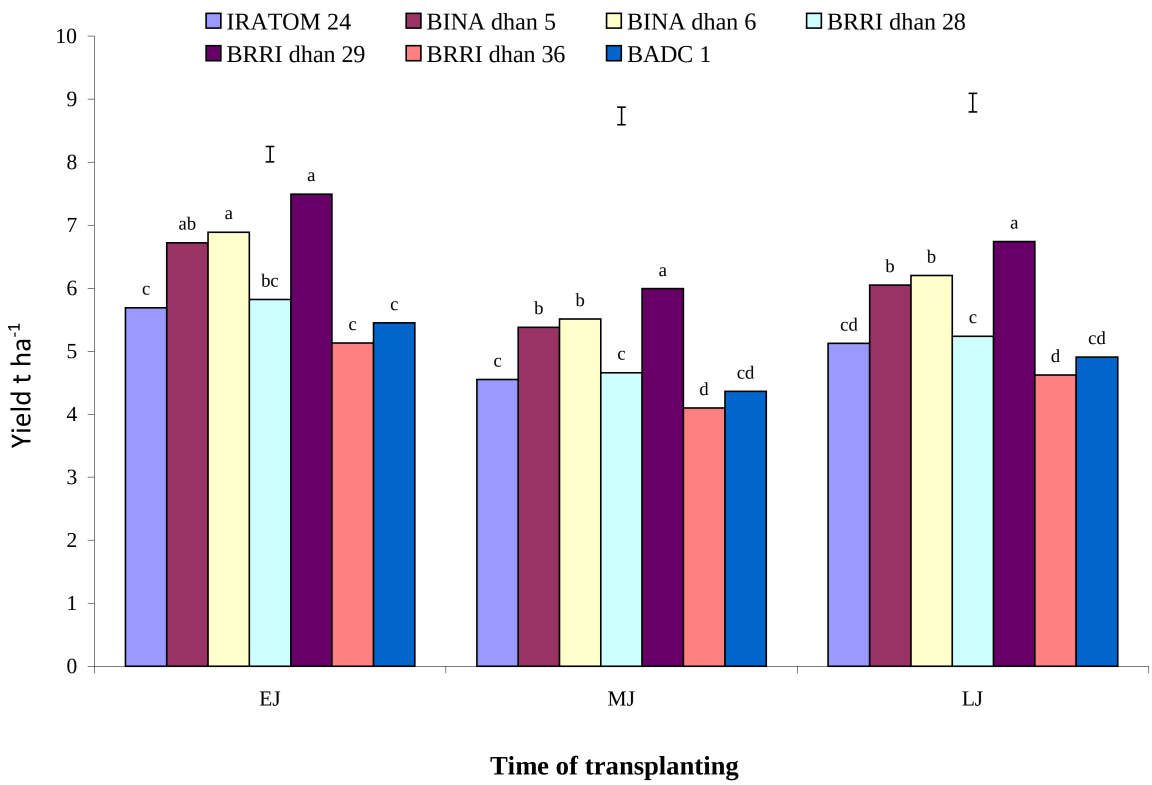


Fig. 22. Yield at different transplanting dates of seven rice varieties in boro season

4.12.2 Stubble ploughing in paddy fields after immediate harvesting in boro season

4.12.2.1 Percentage of infestation of YSB (*S. incertulas*) in ploughing the paddy fields after immediate harvesting in boro season

Stubble ploughing had a significant effect on percentage of infestation (Fig. 23 and appendix XXXVII and XXXVIII). It was found that after immediate harvesting, paddy fields ploughing significantly reduced the infestation of YSB as compared to not ploughing the paddy fields .The range for infestation were 16.26 to 40.22 and 16.26 to 35.36 in not stubble ploughing and stubble ploughing the paddy fields land after immediate harvesting. Five varieties out of seven varieties differed significant % of infestation and indicated that the ploughing after immediate harvesting reduced the % of infestation as compared to not ploughing the paddy fields after immediate harvesting in boro season. It might be, ploughing the paddy fields after immediate harvesting disrupted the life cycle of YSB.

4.12.2.2 Yield of boro rice varieties in ploughing the paddy fields after immediate harvesting

Yield was significantly influenced by stubble ploughing and not stubble ploughing after immediate harvesting. It was found that the stubble ploughing produced higher yield than not stubble ploughing in five varieties out of seven varieties in boro season (Fig. 24 and appendix XXXIX & XL). BRRI dhan29 produced the highest yield in both ploughing and not ploughing the paddy fields just after harvesting. There were no differences in yield at both ploughing and not ploughing the paddy fields after immediate harvesting for the varieties IRATOM24 and BADC1 .The present investigations were in partially agreement with Agrios, 1988.

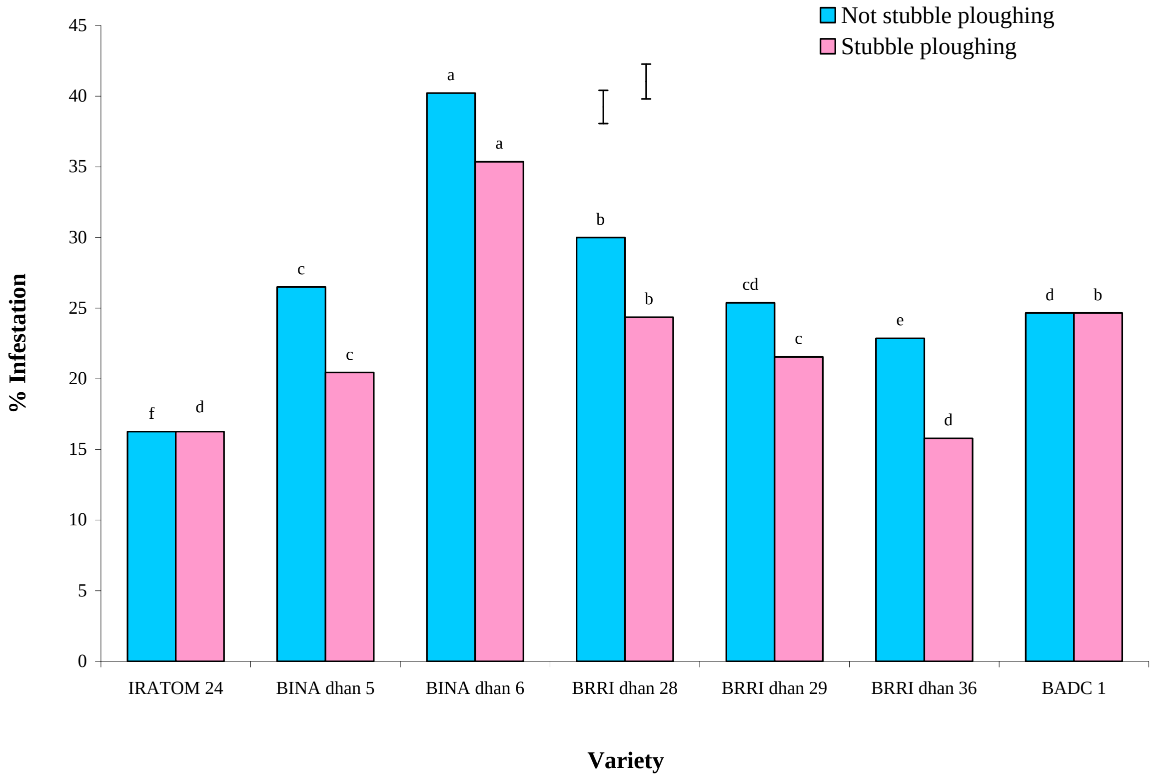


Fig. 23. Percentages of infestation of *Scirpophaga incertulas* at stubble ploughing and non-ploughing the paddy fields after immediate harvesting of seven rice varieties in boro season (2014)

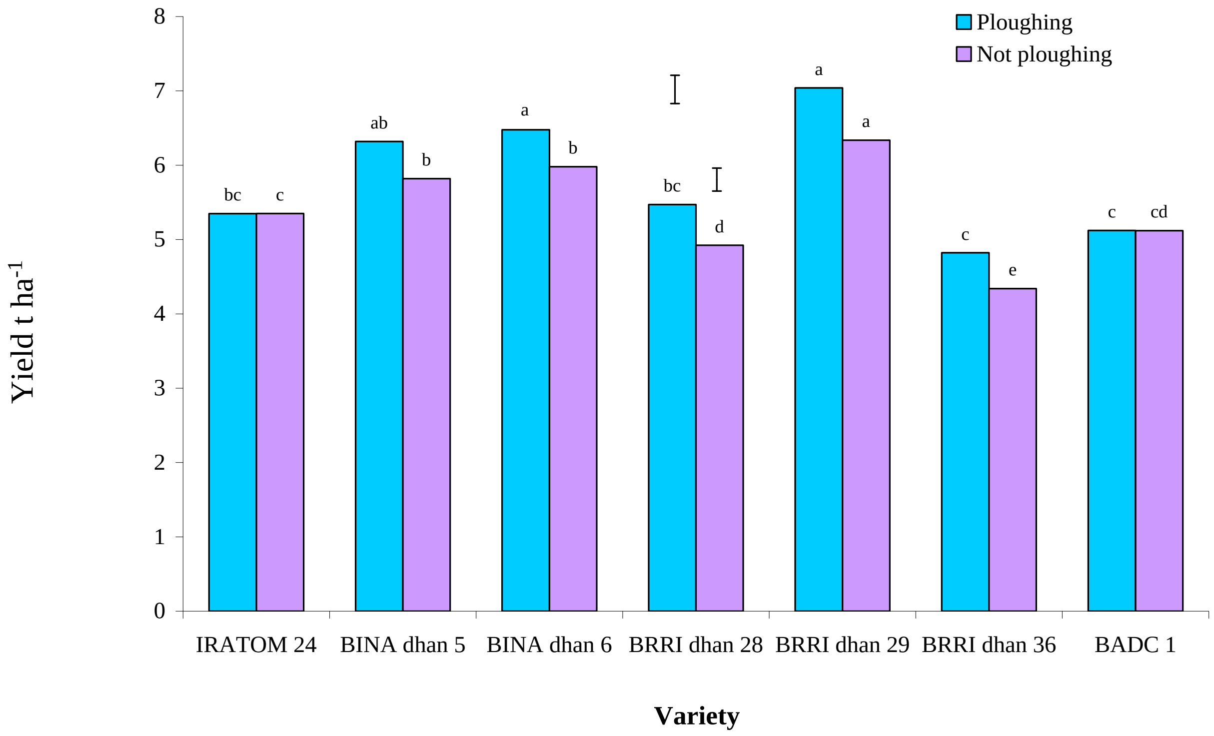


Fig. 24. Yield at ploughing and non ploughing the paddy fields after immediate harvesting of seven rice varieties in boo season (2014)

4.12.3 Flooding the paddy fields after immediate harvesting in boro rice

4.12.3.1 Percentage of infestation of YSB (*Scirpophaga incertulas*) in flooding the paddy fields after immediate harvesting in boro season

Percentage of infestation of YSB was significantly influenced by flooding and not flooding the paddy fields after immediate harvesting (Fig. 25 and appendix XLI-XLII). Result indicated that flooding reduced the percentage infestation than not flooding the paddy fields after immediate harvesting. The range for percentage of infestation were 6.36 to 24.33 % and 3.48 to 22.15 % in not flooding and flooding the paddy fields after immediate harvesting. Flooding might act as barrier to complete the life cycle of YSB smoothly.

4.12.3.2 Yield of boro rice varieties in flooding the paddy fields after immediate harvesting

Yield was also influenced by not flooding and flooding the paddy fields just after harvesting. Not flooding had the lower yields than flooding (Fig. 26 and appendix XLIII & XLIV) in five varieties out of seven. There might be other biotic factors including a biotic factor like temperature, humidity, rainfall, growth environment of the fields and management practices followed during conducting the experiment involved for the variation of percentage infestation of YSB as well as reducing the yields of seven rice varieties in boro season. The present investigations were in partial agreement with Agrios, 1988.

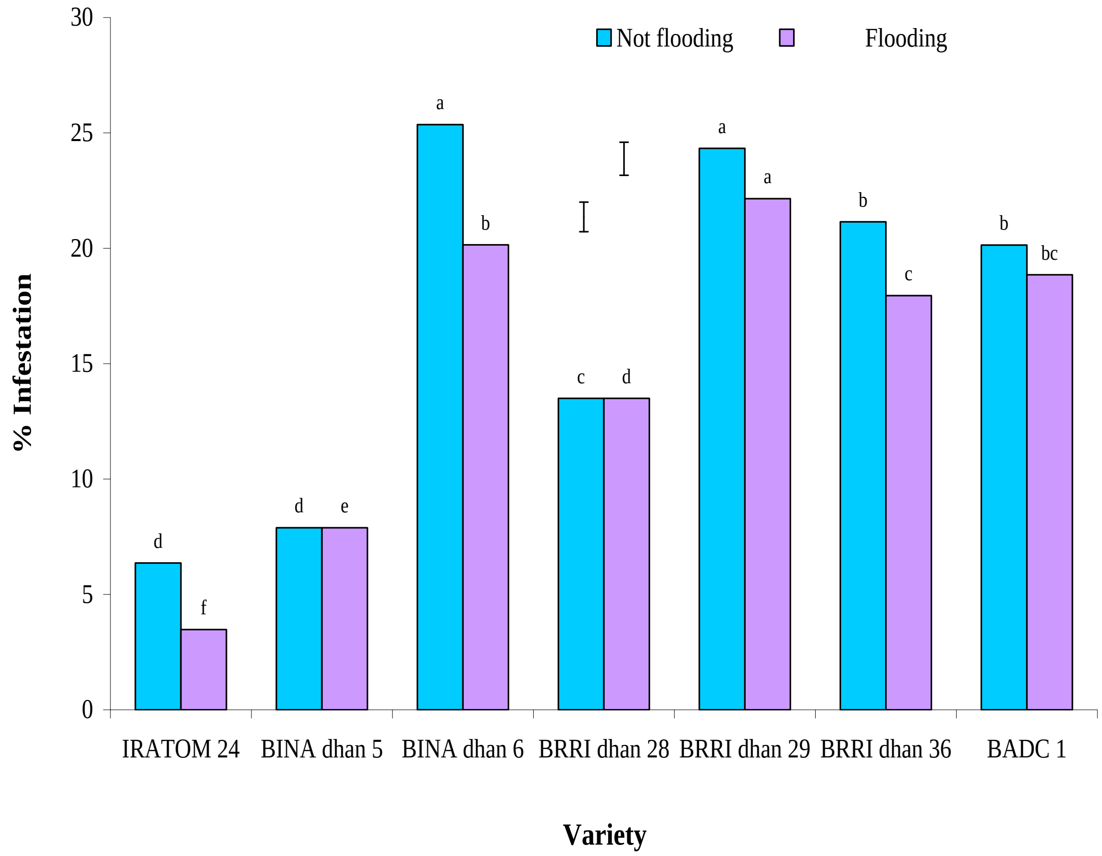


Fig. 25. Percentage of infestation of *Scirpophaga incertulas* with flooding and non-flooding the paddy fields after immediate harvesting of seven rice varieties in boro season (2014)

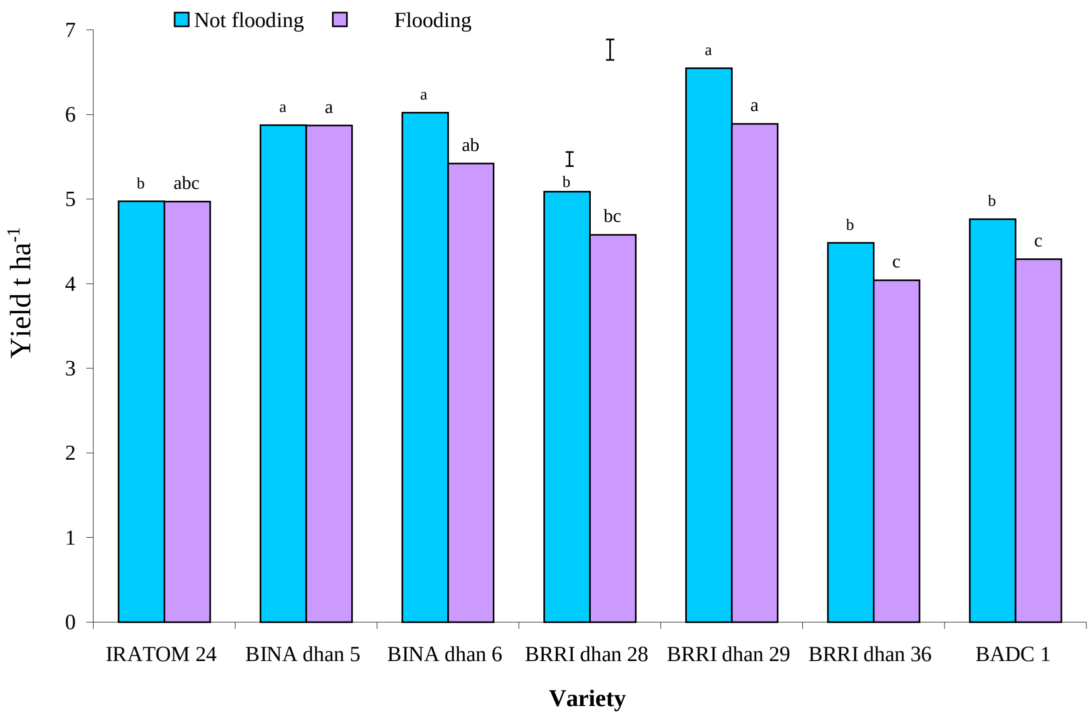


Fig. 26. Yield at flooding and non-flooding the paddy fields after immediate harvesting boro season (2014)

CHAPTER 5
SUMMARY AND CONCLUSION

Research experiment related to the "Relationship between phenological stages of boro rice and the stages of life cycle of yellow rice stem borer (S*cirpophaga incertulas*) in fields" was carried out in the fields of Porabari, Salna, Gazipur, adjacencent to Bangabandu Sheikh Mujibur Rahman Agricultural University, Gazipur, and different laborites of Bangabandu Sheikh Mujibur Rahman Agricultural University and Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka, during the boro season, November, 2010 to May, 2014.The experimental site belongs to the Tista flood plain and Active Tista flood plain of Agro Ecological Zone (AEZ) 8 &9. The field was a medium high land of silty loam texture with pH 5.58-6.8. Experimental treatments consisted of seven modern rice varieties viz. IRATOM24, BlNA dhan5, BlNA dhan6, and BRRI dhan28. BRRl dhan29, BRRl dhan36 and BADC1. The experiment was laid out in a Randomized Complete Block Design with three replications. The area of each unit plot was 10 m^2 (5m × 2m). 35 days old seedling of each variety was transplanted on early January, mid January and late January from 2010 to 2014 at the rate of 2 seedlings $hill^{-1}$ with 20 cm x15 cm spacing. There were five research objectives. Materials used and methods followed during conducting the experiment have been mentioned and discussed under separate heads conforming to the objectives of the research work. All the collected data were analyzed statistically and mean differences were adjusted by DMRT.

The results revealed that the plant height, number of total tillers, number of effective tillers, LAI, CGR, NAR and RGR were significantly varied among the varieties at different phenological stages. It was found that BRRI dhan29 produced the maximum number of effective tiller (10.33), panicle length (26.05 cm) , number of filled grains $panicle^{-1}$ (134.8), 1000 grain weight (24.33 g), grain yield (7.49 ton ha^{-1}) and biological yield (16.41 ton ha^{-1}). The results indicated that the duration of different phenological stages differed significantly among the varieties. For mid-January transplanting time, the seedling started to initiate the tiller from 3rd week of February and continued up to last week of same month. The length for duration of month of seedling stage and vegetative stage were mid-January to mid-February and mid-February to last week of February's. The duration for early reproductive stage, reproductive stage and post reproductive stage of rice varieties were 1st

week of March to 3rd week of March, 4th week of March to 2nd week of April and 2nd week of April to last week of April respectively.

From the biological study of YSB, It was found that the duration of egg to larva, larva to pupa, pupa to adult and total life cycle of YSB were 6. ±0.5 days, 28.2 ± 0.60 days, 8.1± 0.44 days and 42.3±1.25 days respectively.

From the coincidence of phenological stages of rice varieties and the stages of life cycle of YSB it was observed that the adult YSB always appeared maximum at vegetative stage at the 4th week of February in all varieties. Adult arrived and laid eggs at vegetative stage of rice and eggs changed into larvae at the same phenological stage of all rice varieties for mid-January transplanting time in boro season. Larva changed into pupa and pupa changed into adult at reproductive stage and post reproductive stage of rice varieties for same transplanting date. After harvesting the rice varieties, the newly emerged adult eggs were remained in the stubble of paddy fields. This coincidence of two biotic aspects (rice varieties and YSB) continued among the distinct phenological stage of rice and the specific life stage of YSB *(S.incertulas*) in three different rice growing seasons (aus, aman and boro) in Bangladesh throughout the year. Number of egg masses was always significantly higher at mid-January transplanting time than at early and late January transplanting time of different phenological stage of seven rice varieties. It was found that the adult YSB always appeared maximum at last the week of February at the vegetative stage of seven rice varieties for mid-January transplanting time, in boro season. Therefore the mid-January transplanting time of rice varieties in boro season might be made a temporal favorable coincidence between the each life stages of YSB and the different phenological stages of rice varieties.

The mean number of egg masses deposited by YSB (*S. incertulas*) in two boro seasons was found to be a partially different. In the year 2013 highest number of egg masses was recorded in BRRI dhan 36 which significantly differed from that of other varieties. The lowest number of egg masses was observed in BADC1. Regarding the location of egg masses on the rice leaf, the middle portion was preferred more for egg laying than basal and apical portions. Highest number of egg masses was deposited on basal portion in BRRI dhan28, on middle portion in BINA dhan6 and on apical portion in IRATOM24. There was no egg deposition on apical portion in BRRI dhan28, BRRI dhan29, BRRI dhan36 and BADC1.From the monthly pattern of occurrence it was found that the YSB occurred in large number during August to November and April to June. In December to February abundance of YSB observed comparatively very low. However, population of YSB began to increase from March to April and first peak of the year occurred during the month of May.

From the nature of damage, it was found that the infested hills as well as infested tillers were maximum at preflowerng stage and minimum were in active tillering stage in all varieties. On the other hand, infested tiller without appearing any symptom highest was in flowering stage and lowest was in preflowering stage in all varieties. Though the 'Dead heart' (DH) and 'White head' (WH) formation observed through stem dissection were maximum in preflowering stage in all varieties but in case of direct field count, active tiller stages produced the highest % of 'Dead heart' (DH) and 'White head' (WH) as compared to flowering stage in all varieties. It was found that the number of egg masses were significantly higher at vegetative stage than other phenological stages of seven rice varieties at all three different transplanting time.

From the control measures, it was observed that the vegetative stage for early January transplanting time and late January transplanting time were 1^{st} week to 3^{rd} week of February and 1^{st} week to 2^{nd} week of February respectively. As the adult YSB appeared at the last week of February at vegetative stage of rice, so when the rice varieties were transplanted at early and late January instead of mid-January, the vegetative stage of rice varieties did not appear at last week of February. There might be less adult arrived as well as less egg laid mainly due to the absence of vegetative stage at the last week of February for early and late January transplanting time instead of mid-January transplanting. It was also found that early- January and late January transplanting time produced the more yield ton ha^{-1} as compared to mid-January transplanting time. Stubble ploughing had a significant effect on percentage of infestation. It was observed that after immediate harvesting, stubble ploughing from the paddy fields significantly reduced the infestation of YSB. Yield was significantly influenced by stubble ploughing after immediate harvesting. It was found that the stubble ploughing produced higher yield than non- stubble ploughing in five varieties out of seven varieties in boro season. Percentage of infestation of YSB was significantly influenced by flooding the paddy fields after immediate harvesting. Results indicated that flooding reduced the percentage of infestation after immediate harvesting. Yield was also influenced by flooding the paddy fields just after harvesting. Non- flooding had the lower yields than flooding in five varieties out of seven in boro season.

Finally it may be concluded that YSB activity concealed with the phenological stages of rice varieties and it can be controlled in the fields culturally by careful selection of a suitable transplanting time. Considering the prevalence of appearing of optimum phenological stage of rice and the adult YSB arrival time, percentage of infestation as well as rice yield, the best time for transplanting rice seedling in boro season would be early or late January instead of mid- January. Moreover, the stubble ploughing and flooding the paddy fields after immediate harvesting reduced the percentage of infestation of YSB and increased the yield of rice in boro season. Thus the present study investigates the possibilities of introduction of a pest (YSB) management method in to the agricultural sectors both nationally and globally in order to overcome the negative impacts on environment, economic and social sectors without harming the food chain and yield of rice via the sustainable agricultural concept. Knowledge of all these newly revealed capacities of plats and insects forces us to reexamine our ideas of ecological relationships and evolutionary hypotheses. It is hoped that the findings of the present study will help the rice entomologist in developing a pest management programme for YSB (*Scirpophaga incertulas*) and stimulate research workers in taking up further studies in these lines for a sustainable bio- resource management.

CHAPTER 6

REFERENCES

Abraham, C.C., Thomas, B., Karunakaran, K. and Gopalakrishnan, R.O. 1972. Effect of planting seasons and the associated weather condition in the incidence of the rice stem borer, *Tryporyza incertulas* Walker, Agric. Res. J. Kerala, **10** (2): 141-151.

Adiroubane, D. and Raja, K. 2010. Influence of weather parameters on the occurrence of yellow rice stem borer, *Scirpophaga incertulas* (Walker). J. Rice Res., **3** (1): 5-9.

Agrios, G. N. 1988. Plant pathology, 3rd edition. Academic Press, INC. San Diego, New York, Berkeley, Boston, London, Sydney, Tokyo, Toronto.

Akinsola, E.A. 1973. Resistance to the yellow borer, *Tryporyza incertulas* (Walker) in rice varieties. M.S. Thesis, Faculty of the College of Agriculture, University of the Philippines at Los Banos, Laguna, the Philippines. 79 p.

Alam, M.Z. 1964. Insect pests of rice in East Pakistan. In: The Major insect pests of the rice plan*t*. Johns Hopkins Press, Baltimore, Maryland. 643-655 pp.

Alam, M.Z. 1965. Insect pests of rice in East Pakistan and their control. Revised edition. Agric. Information Service. Government Press, Dhaka. 92 p.

Alam, M.Z. 1967. Insect pests of rice in East Pakistan. In: The Major insect pests of the rice plant. Johns Hopkins Press, Baltimore, Maryland. 643-655 pp.

Alam, M.Z., Ahmed, A. and Ali, S. 1964. Field tests of insecticides against rice borers in East Pakistan. Pakistan J. Sci. **16** (5): 259-262.

Alam, M.Z., Alam, M.S. and Abbas, M. 1972. Status of different stem borers as pests of rice in Bangladesh. Int. Rice Comm. News1. **21** (3): 15-17.

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

Alam, S. and Catling, H.D. 1977. Preliminary observations of deep water rice pests in Bangladesh. In*: international Rice Research Institute.* Proc. Deep Water Rice Workshop, 8-10 November, 1976. Bangkok. 205-210 pp.

Alam, S. and Quraishi, N. 1976. Species composition of rice stem borers and their seasonal abundance at Joydevpur, Dhaka. Paper presented at 1st Bangladesh Science Conference, Dhaka 3 p.

Alam, S., Catling, H.D., Karim, A.N.M.R., Alam, M S. and Quraishi, N. 1981. Checklists of rice insects in Bangladesh. Bangladesh J. Zool. **9** (2): 91-96.

Alam, S., Karim, A.N.M.R. and Ahmed, M.S. 1985. Researches on rice stem borers at Bangladesh Rice Research Institute, Entomology, BRRI, Joydevpur. 163 p.

Anwar, M.P. 1999. A study on the productivity of rice and fertility of soil as influenced by variety and nitrogen fertilization.M.S. Thesis, Dept. Agron. Bangladesh Agril. Univ., Mymensingh. 121 p.

Areekul, S. and Chamchanya, T. 1973. Effects of humidity, temperature and light on the growth and development of *Sesamia inferens* (Walker). Kasetsart J. **7** (2): 65-75

Arjunan, A., Natarajaratnam, N., Nagarajan, M., Sadasivam, R. and Balakrishnan, K. 1990. Photosynthesis and productivity in rice cultivars. Photosynthetica. **24** (2): 273-275.

Arvind, A. 1987. Host plants for yellow rice borer (YSB), *Scirpophaga incertulas* and White stem borer (WSB), *Scirpophaga innotata.* Int. Rice Res. Newsl. **12** (3):33.

Atwal, A.S. and Dhaliwal, G.S. 2005. Agricultural Pests of South Asia and their management. Kalyani Publishers, New Delhi. 181-182 pp.

Banerjee, S.N. and Prarnanik, L.M. 1967. The Lepidopterous Stalk Borers of Rice and their Life Cycles in the Tropics. In: The Major Insect Pests of the Rice Plant.. Johns Hopkins Press. Baltimore, Maryland. 103-124 pp.

Barr, B.A.,Koehler, C.S. and Smith, R.F. 1975. Crop losses to insects, diseases, weeds and other pests. USAID. Pest management and related environmental protection project University of California, Berkley. 64 p.

Barrion, A. T. and Litsinger, J .A. 1981. Nomenclatural changes for some rice insect pests. Int. Rice Res. Newsl. **6** (4): 14.

Bashar, Labeyrie, V., Hossaert, M., Fabres, G. and Valero, M. 1987. *Bruchus affinis* and the flowers of *Lathyrus latifolius*: An example of the complexity of relation between plants and phytophagous insects. Insect-plants @1987 Dr. W. Junk publisher, Dordrecht. ISBN 90-6193-642-X. Printed in the Netherlands. 189 p.

Bashar, M. A. 2004. Instant Basics of Environment: Wide approach to nature lover. 1st ed. Positron publications. 38/2/ka Banglabazar, Dhaka-1100. 578 pp.

Bashar, M. A. 2010a. Sustainable use of biodiversity: Bracing the change. The Daily Star (Environment). April 10, 2010.

Bashar, M. A. 2010b. Innovating biotic technique for conservation of forest and wildlife. The Daily Independent (Science & Technology). April 21, 2010.

Bashar, M. A. 2012. Butterfly colonization, biodiversity conservation and ecotourism. The Daily Independent. (Science & Technology), June 22, 2012.

Bashar, M. A. 2013. Assemblage of flora and fauna. The Daily Independent. (Science & Technology) May 27, 2013.

Bashar, M. A. 2015. Butterflies of Bangladesh. Vol-2 (EBBL Red-List and butterfly activities). 1st ed. BCTF publications. 182 pp.

Bashar, M. A., Mamun, M. A., Aslam, F. M. and Chowdhury, M. A. K., 2006. Biodiveristy Maintenance and Conservation of Butterfly-Plant Association in some Forest of Bangladesh. Bangladesh J. Zool. **34** (1): 55-67.

Behera, I. 1998. In. Japonica Rice. Its Breeding and culture, Yokendo, Ltd. Tokyo, 511-514. pp.

BINA (Bangladesh Institute of Nuclear Agriculture). 1993. Annual Report for 1992-93. Bangladesh Inst. Nuclear Agric., P.O. Box No. 4. Mymensingh. 143p.

BINA (Bangladesh Institute of Nuclear Agriculture). 1998. Technical report on hybrid rice Alok 6201. Div. of Agron., Bangladesh Inst. Nuclear Agric., P.O. Box No. 4, Mymensingh.1-3 pp.

BINA (Bangladesh Institute of Nuclear Agriculture). 2001. Leaflet. Published by Bangladesh Inst. Nuclear Agric., P.O. Box No. 4, Mymensingh. 2 p.

Biswas, J.W., Hossain, M.A., Sarker, B.C., Hansan, M. and Haque, M.Z. 1998. Yield performance of several rice varieties seeded directly as late aman crops. Bangladesh J. Life Sci. **10** (1&2): 47-52.

Bora, D. K., Saharia, D. and Hussain, S., 1994. Biology of yellow stem borer, *Scirpophaga incertulas* (Wlk.), *Crop Res.,* Hissar, **8**: 366-370.

BRRI (Bangladesh Rice Research Institute).1984. Pest Management. *In: Annual Report..* Joydcvpur. Gazipur, Bangladesh. 235 p.

BRRI (Bangladesh Rice Research Institute) .1987. Annual Report for 1985. Joydebpur, Gazipur. 64-65 pp.

BRRI (Bangladesh Rice Research Institute). 1991. "Adhunik Dhaner Chash" Bangladesh Rice Res. Inst. Joydebpur, Gazipur, Dhaka. (in Bengali). 133 p.

BRRI (Bangladesh Rice Research Institute). 1994. Annual Report for 1993. Bangladesh Rice Res. Inst. Joydebpur, Gazipur. 8-9 pp.

BRRI (Bangladesh Rice Research Institute). 1996. Annual report for 1995. Bangladesh Rice Res. Inst. Joydebpur, Gazipur. 7-11 pp.

BRRI (Bangladesh Rice Research Institute). 1999. "Adhunik Dhaner Chash" Bangladesh Rice Res. Inst. Joydebpur, Gazipur. (in Bengali). 7-17 pp.

BRRI (Bangladesh Rice Research Institute). 2000. Annual Report for 1999. Bangladesh Rice Res. Inst. Joydebpur, Gazipur. 8-9 pp.

Burondkar, M.M., Chavan, S.A., Jdhav, B.B. and Birari, S.P. 1998. Physiological basis for varietal differences in yield of early rice varieties. J. Mharashtra differences in yield of early rice varieties. Maharashtra Agric. Univ. **13** (3): 343-344.

Buttery, B.R. 1970. Effect of variation in leaf area index on growth of rice. Crop Sci. **10**:9-12.

Catling, H.D. 1979. Crop losses in deep water rice due to yellow rice borer. Int. Rice Res. News1. **4** (5): 14-15

Catling, H.D. and Alam, S. 1977. Rice Stem borers. *In: Literature Review of Insect Pests and Diseases of Rice in Bangladesh*, BRRI, Joydevpur, Gazipur, Bangladesh. 5-29 pp.

Catling, H.D. and Islam, Z. 1979. Stem borer incidence in the 1977 Bangladesh deep water rice crop. In: Proceedings of the I978 International Deep Water Rice workshop. International Rice Research Institute, Los Banos, the Philippines. 215-225 pp.

Catling, H.D. and Islam, Z. 1982. The Problem of Yellow Rice Borer in Asian Deep Water Rice. In: Proceedings of the 1981 International Deep Water RiceWorkshop. International Rice Research Institute, Los Banos, the Philippines. 451-458 pp.

Catling, H.D., Alam, S. and Miah. S.A. 1978. Assessing losses in rice due to insects and diseases in Bangladesh. Expt. Agric. **14**:277-287.

Chamblish, C.E. 1920. Prairie rice culture in the United States. In: USDA Farmers Bull.1092.26 p.

Chandra, B.V., Mahadevappa, M., Krisnmurthy, A.H. and Bhaskar, V. 1992. Performance of IRRI rice hybrid in Mandya, Karnataka, India. Intl. Rice Res. Newsl. **17** (2): 6.

Chandra, K. and Das, A.K. 2000. Correlation and intercorrelation of physiological parameters in rice under rainfed transplanted condition. Crop Res. Hisar, Assam, Agric. Univ. **19** (2): 251-254.

Chandramohan, N. and Chelliah, S. 1983. Rice Resistance to yellow stem borer. Int. Rice Res. Newsl. **8** (2):8.

Chaudhary, G.Q., Halimie, M.A. and Azhar, I. 1976. Population study of moths of rice stem borers in Gujranwala District. Pakistan. Rice Ent. Newsl. **4**: 27-28.

Chaudhary, R.C., Khush, G.S. and Heinrichs, E.A. 1984. Varietal resistance to rice stem borers in Asia. Insect Sci.Appl. **5**: 447-463.

Chen, W.F., Xu, Z.J., Zhan, L.B. and Yuang, S.R. 1991. Studies on canopy properties and their relationship to dry matter production in Japonica rice cultivars with different plant types. Chinese J. Rice Sci. **5** (2): 67-74.

Cho, D.S., Jong, S.K., Son, S.Y. and Park, Y.K. 1988. Studies on the duration and rate of grain filling in rice. Differences between parts of a panicle. Korean J. Crop Sci. **33** (1): 5-11.

Chowdhury, D. and Ghosh, A.K. 1978. Evaluation of agronomic and physiological characters of fine and scented rice varieties. Indian J. Agril. Sci. **48** (10): 373-378.

Chowdhury, M.J.U., Sarker, A.U., Sarker, M.A.R. and Kashem, M.A. 1993. Effect of variety and number of seedlings hill' on the yield and its components on late transplanted aman rice. Bangladesh J. Agril. Sci**. 20** (2): 311-316.

Chowdhury, S.A., Majid, M.A., Haque, K.S., Islam, M. and Rahman, M.M. 1995. Effect of variety in yield and nutritive value of rice straw, Australian J. Animal Sci. **8** (4): 329-335.

Cia, Q.S. and Wu, Z.S. 1993. The relations between dry matter accumulation at different growth stages and grain weight of wheat. J. Nanjing Agril. Univ. **16** (1): 27-32.

Cork, A., Souza, K. D., Krishnaiah, K., Reddy, A. A. and Zainulabuddin, S. 1998. Season-long control of yellow stem borer, *Scirpophaga incertulas* (Lepidoptera:Pyralidae) by mating disruption with the natural ratio of pheromone components. Bull. Of Entomol. Res., **88** (2):109-116.

Cotterell, G.S. 1954. Notes on insect injuries to crops in Afghanistan. FAO Plant Prot. Bull **3**: 53-55.

Cui-jing, Kusutani, A., Toyata, M., Asanuma, K. and Cui, J. 2000. Studies on the varietal differences of harvest index and morphological characteristics of rice. Japanese J. Crop Sci. **69** (3): 359-364.

Dani, R.C. and Jena, M. 2008. Use of sex pheromone in the management of rice yellow stem borer, *Scirpophaga incertulas.* National Seminar on Pheromone Technologies: Strengthening Eco friendly Agriculture in India.19 pp.

Davis, F.M. and Vega, C.R. 1982. An improved oviposition cage for rice stem borers. Int. Rice Res. Ncwsl. **7** (3): 7-8.

Dethier, V. 1953. Host perception in phytophagous insects. In: Symposium on Physiological Relations between Insects and their host-plant, Trans. IXth International Congress of Entomology, Amsterdam. **2**: 81-89 pp.

Dethier, V. 1978. Studies on insect-plant relations-past and future. In: Proceedings of the IVth international Symposium on Insect-Plant Relationships (R.F. Chapman & E.Bernays, eds), Nederl. Entomol. Vernung pub. 759-766 pp.

Dethier, V.1986. Concluding remarks. Insects-Plants. In: Labeyrie, V., Fabres, G. and Lachaise D. (eds.). 1987. Dr. Junk Publishers, Dordrecht, the Netherlands.

Diaz, S.H., Castro, R. and Morejon, R. 2000. Morpho-agronomic characterization of varieties of rice. Instituto Nacional de ciencias Agricolas, Gaveta Pstall, San Jose, de las, Lajas, La Habana, Cuba, **21** (3): 81-86.

Djamin, A. and Pathak, M.D. 1967. The role of silica in resistance to Asiatic rice borer, Chilo *suppressalis* (Walker) in rice varieties. J. Econ. Ent. **60**: 347-351.

Douglas, W.A. and Ingram, J. W. 1942. Rice field insects. USDA Circular No. 632. 32p

Ehrlich, P. R. and Raven, P. R. 1964. Butterflies and plants: A study in coevolution. Evolution. **18**. 586-608.

Evans, L.T. 1975. The physiological basis of crop yield. Crop Physiol. Camb. Univ. Press. Cambridge. 327-355 pp.

Feeny, P.P., 1976. Plant apparency and chemical defence. In: Wallace, J. W., and Mansell, R. L. (eds.). Biochemical interactions between plants and insects. Plenum, New York. 1-40 pp.

Fernando, H.E. 1967. Insect pest of rice in Ceylon.. In: Major Insect Pests of Rice Plant. Johns Hopkins University Press, Baltimore, Maryland. 575-589 pp.

Fraenkel G.S., 1959. The raison d`etre of secundary plant substances. Science **129**: 1466-1470.

Fu, G., Cf., L., MI, L. and Js, Z. 1991. Studies on physiological basis of high yield of *indica Japonica* hybrid rice Yayou 2. Jiangsu. J. Agril. Sci. **7** (1): 15-19. [CAB Abst. 1990-91].

Fukaya, M. 1947. Fundamental studies on the forecasting of outbreaks of the rice stem borer. III. Relation of the percentage of infested stem to the varieties of rice. [In Japanese]. Nogaku Kenkyu, Agr. Res. Sta. **27**: 97-99.

Fukaya, M. 1967. Physiology of Rice Stem Borers Including Hibernation and Diapause. In: The Major Insect Pests of the Rice Plant. Johns Hopkins Press, Baltimore, Maryland. 213-227 PP.

Fukaya, M. and Nakatsuka, K. 1956. Forecasting of the rice stem borer occurrence [*In* Japanese] . Japan Plant Prot. Assoc. Tokyo. 173 p.

Gardner, F.P., Pearce, R.B. and Mitchell, R.L. 1985. Physiology of Crop Plants. Iowa State Univ. Press, Iowa.66-84 p.

Ghosh, B.N. 1960. A note on the resistance of boro paddy to stem borer infestation. Sci. Cult. **25**: 547-548.

Gomez, K.A. 1972. Estimation of yield losses caused by stem borers.IRRI. Saturday Seminar, July 15, 1972. Los Banos, the Philippines. 33 p.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. Second Edition. Int. Rice Res. Int. John Wiley & Sons. New York. 680 p.

Guowei, W., Loyold, T. Wilson and Anna, M.M. 1998. Contribution of rice tillers to dry matter accumulation and yield. Agron. J**. 90** (3):317-323.

Gupta, J.C., Katich, P.C., Kaushik, R.P. and Sharma, S.L. 1998. Cause and effect of relationship of yield and its components under cold stress condition in rice (*Oryza sativa*). Indian J. Agric. Sci. **68** (1): 13-15.

Gupta, S.P., Pandey, U.S., Pandey, V. and Mishra, C.H. 2002. Screening of rice cultivars under wet condition against major insect pests of rice. *Shashpa*, **9** (2): 189-190.

Haloi, B. and Baldev. B. 1986. Effect of irrigation on growth attributes in chickpea when grown under different dates of sowing and population pressure. Indian J. Plant Physiol. **29**: 14-27.

Haque, D.E. 2002. Effect of Madagascar technique of younger seedling and wider spacing on growth and yield of boro rice. M.S. Thesis, Dept. Agron. Bangladesh Agril. Univ, Mymensingh. 28-71 pp.

Hassanein, M.H. 1959. Nocturnal activity of insect as indicated by light traps. Bull. Soc. Entom. Egypt. **40:** 463-479.

Heinrichs, E.A., Medrano, F.G. and Rapusas, H.R. 1985. Genetic evaluation for insect resistance in rice. IRRI, Los Banos, Laguna, the Philippines. **356 p.**

Honarneijad, R. 1995. Study on correlation among some morphological characters in six Iranian rice genotypes. Seed and Plant. **119** (4): 37-52.

Hossain, S.M.A. and Alam, A.B.M. 1991. Performances of different varieties of boro rice. In: Fact Searching and Intervention in two FSRDP Sites. Activities 1989-90. Farming Syst. Res and Devel. Prog. Bangladesh Agril. Univ., Mymensigh. 19-20 pp

Huang, N.R., Zhaung, S.U., Huang Qiumei, Liu, Uanzhuo. 1999. Morphological and physiological characteristics of two-line rice hybrid Yueza 122 with fine grain quality and high yielding potential. J.Trop. Sub-trop. Bot. **11**:62-69.

Hussain, T., Jilani, G. and Gaffer, M.A. 1989. Influence of rate and time of N application on growth and yield of rice in Pakistan. Int. Rice Res. Newsl. 14: 18.

Idris, M. and Matin, M.A. 1990. Response of four exotic stains of aman rice to urea. Bangladesh J. Agril. Sci. **17** (2): 271-275.

IRRI (International Rice Research Institute). 1964. Entomology. In: Annual Report Jar. 1963. Los Banos, the Philippines. 119-134 pp.

IRRI (International Rice Research Institute). l965. Entomology. In:: Annual Report for 1964. Los Banos, the Philippines.157-185 pp.

IRRI (International Rice Research Institute). 1972. Entomology. In: Annual Report for 1971. Los Banos, the Philippines.117-140 pp.

IRRI (International Rice Research Institute). 1974. Entomology. In: Annual report for 1973. Los Banos, Philippines. 209-233 pp.

IRRI (International Rice Research Institute). 1975. Genetic evaluation and utilization (GEU) programme. Insect resistance. Control and management of insects. In: Annual Report for 1974. Los Banos, the Philippines. 85-91. pp.

IRRI (International Rice Research Institute). 1977. Genetic evaluation and utilization (GEU) programme. Insect resistance. Control and management program of rice pests. Insects. In: Annual Report for 1976. Los Banos, the Philippines. 54-61 pp.

IRRI (International Rice Research Institute) .1978. Genetic evaluation and utilization (GEU) programme. Insect resistance. Control and management of rice pests. Insects. In: Annual Report for 1977. Los Banos, the Philippines. 61-72 pp.

IRRI (International Rice Research Institute). 1980. Standard Evaluation System for Rice, Los Banos, the Philippines. 44 p.

IRRI (International Rice Research Institute) .1987. Genetic evaluation and utilization (GEU) programme. Insect resistance. Control and management of rice pests. Insects. In: Annual report for1986. Los Banos, the Philippines. 83-98 pp.

Ishii, S., Hirano, C., lwata. Y., Nakaswa, M. and Miyagawa, H. 1962. Isolation of benzoic and salicylic acids from the rice plants as growth inhibiting factor for the rice stem borer, *Chilo suppressalis* (Walker) and some rice plant fungus pathogens. Jap. J. Appl. Ent. Zool. **6**: 281-288.

Islam, Z. 1991. Rice yellow stem borer (YSB) egg deposition preferences. Int. Rice Res. Newsl. **16** (3): 24

Islam, Z. and Catling, H.D. 1991. Biology and behaviour of rice yellow stern borer in deepwater rice. Journal of Plant Prot. Tropics [(c) Malaysian Plant Protection Society]. **8** (2): 85-96.

Israel, P. 1967. Varietal resistance to rice stem borers in India. In: The Major Insect Pests of the Rice Plant. Johns Hopkins University Press, Baltimore, Maryland.391-403 pp

Israel, P., Rao. Y.S., Prakasa Rao, P.S. and Dinabandu, B. 1965. The origin of stem borer infestation in summer crop of rice and its control. Oryza. **2** (1): 155-161.

Jepson, W.F. 1954. A Critical Review of the World Literature on the Lepidopterous stalk Borers of Tropical Graminaceous Crops. CIE, London. 127 p.

Jermy, T., 1988. Can predation lead to narrow food specialization in phytophagous insects? Ecology. **69**: 902-904.

Jodon, N.E. and Ingram, J.W. 1948. Survey of rice varieties for possible resistance to stalk borers. Rice J. 51: 28.

Julfiquar, A.W., Haque, M.M., Hoque, A.K.G.M.E. and Rashid, M.A. 1998. Current status of hybrid rice, research and future programme in Bangladesh. A country report presented in the workshop on use and development of hybrid rice in Bangladesh. May 18-19, Bangladesh Agril. Res. Counc. Dhaka, Bangladesh.

Julfiquar, A.W., Hossain, M.A., Ansari, T.H. and Islam, M.A. 1997. The augmented design as an aid to preliminary selection of new rice hybrids. Bangladesh J. Life Sci. **9** (1): 23-29.

Kabaki, K., Hasegawa, H., Yamaguchi, H. and Kon, T. 1992. Growth and yield of *Japonica indica* hybrid rice. Bull. Hokuriku Newsl. Agril. Exp. Sta. **34**: 1-139.

Kailasam, C., Babu, R.C., Vijayalakshmi, C. and Rangassamy, S.R.S. 1989. A functional growth analysis model for grain development in *Oryza sativia* LJ. Agron. Crop Sci. **162** (5): 354-356.

Kalode, M. B. and Israel, P. 1970. Persistence of insecticidal residues on rice plant against stem borer, *Tryporyza incertulas.* Oryza. **7** (1): 85-90.

Kamal, A.M.A., Azam, M.A. and Islam, M.A. 1988. Effect of cultivars and NPK combinations on the growth and yield contributing characters of rice. Bangladesh J. Agril. Sci. **15** (1): 105-110.

Kamran, M.A. and Raros, E.S. 1968. Seasonal fluctuations in abundance of various rice stem borer on Luzon Island, the Philippines. J. Econ. Ent. **61** (3): 650-665.

Kapur, A.P. 1967. Taxonomy of the rice stem borers. In: The Major insect Pests of the Rice Plant. Johns Hopkins Press, Baltimore, Maryland. 3-43 pp.

Khan, M.A.H. 1981. The effects of carbondioxide enrichment on the pattern of grown and development in rice and mustard. Ph.D. Dissertation. Royal Vet. Agril. Univ., Copenhagen.104 p.

Khan, M.R. and Baloch, U.K. 1967. Varietal resistance to riee borers (Abs) Proc. Pakistan Sci. Conf. 18/19, B. 41.

Khan, Z.R., Litsinger, I.A., Barrion, A.T., Villanueva, F.F.D., Fernandez, N.J. and Taylo, L.D. 1991. World bibliography of rice stern borers, 1794-1990. International Rice Research Institute, Los Banos, the Philippines and International Centre of lnsect Physiology and Ecology. Nairobi, Kenya .415p.

Khusakul, V., Saringkaphaibul, C., Ruay-Aree,S. and Pattrasudhi, R 1977., Current status of rice stem borers in Thailand and possibilities for integrated control. Thai J. Agric. Sci. **10:**41-58.

Kiritani, K. and Iwao, S. 1967. The Biology and life cycle of *Chilo suppressalis* (Walker) and *Tryporyza (Schocnobius) incertulas* (Walker) in temperate-climate areas. In*:* The Major Insect Pests oj the Rice Plant. Johns Hopkins Press, Baltimore, Maryland. 45-101 pp.

Kobata, T. and Moriwaki, N. 1990. Grain growth rate as a function of dry matter production rate: an experiment two rice cultivars under different radiation environments. Korean J. Crop Sci. **35** (2): 187-190.

Koehler, C.S. 1971. Stem borer problems in West Pakistan. Paper presented at the Int. Rice Res. Conf. April l971. International Rice Research Institute, Los Banos, the Philippines. 9 p.

Kojima, K. Inoue, T. and Kishirnoto, R. 1955. The size and oviposited place of the egg mass of the paddy borer *(Schoenobius incertellus* Walker). [In Japanese, English summary]: Res. Rep., Kochi Univ. **4** (17): 1-6.

Koller, R.P. 1970. Development changes in leaf area index and other growth parameters in chickpea. Indian J. Agric. Sci. **50**. 648-691.

Korat, D.M. and Patel. C. B., 1988. Biology of yellow stem borer, *Scirpophaga incertulas* (Wlk.) on rice. Gujarat Agril. Univ. Res. J., **14**: 11-16.

Koshiary, M.A., Pan, C.L., Zaid, l.S.A., EI Halk, G., Azizi, A., Hindi, C., Sirry, 1. Said, A. and Masud, M. 1957. A study on the resistance of rice to stem borer infestation. Int.Rice Comm. Newsl. **6**: 23-25.

Koyama, J. 1973. Studies on the diminution of insecticide application to rice stem borer, *Chilo suppressalis* Walker. 1. The relation between damage caused by rice stem borer and the yield of rice. Jap. J. Appl. Ent. Zool. **17**: 147-153.

Koyama, T. 1955. Studies on the paddy borer (*Schoenobius incertulas* Walker). I. On the seasonal appearance and the environmental resistance concerning the paddy borer. Nogyo-Kairyo-Gieitu-Siryo, **53**: 160-174.

Koyama, T. 1956. Damage by rice stem borer, *Chilo suppressalis,* and its control method in Tohoku District. Agric. and Hort. **31**(1):71-74.

Kulshrestha, J.P., Kalode, M.B., Prakasa Rao, P.S., Misra, B.C. and Verma, A. 1970. High yielding varieties and the resulting changes in the pattern of rice pests in India. Oryza. **7:** 61-64.

Kumar, S., Maurya, R.P. and Khan, M.A. 2007. Impact of bio-intensive pest management strategies on yellow stem borer and leaf folder in rice and their effect on the economics of production. J. *Entomological Res.*, **31** (1): 11-13.

Labeyrie, V., 1970. Signification adaptative de l`integration des signauxfournis par le milieu exterieurlors de l`ovogenese des insects. In: L`influence des stimuli externessur la gametogenese des insects (V. Labeyrie, ed) C.N.R.S. Pub, Paris. 21-43 pp.

Lee, D.J., Vergon, B.S., Zamora, O.B., Kim, B.K. and Chae, J.C. 1992. Development of vascular bundles in the panicle of different tillers and its relationship to panicle of different tillers and its relationship to panicle characteristics of rice. Korean J. Crop Sci. **37** (2): 155-156.

Lim, J.T., Shin, D. Y. and Kim, H.J.S. 1993. Growth and yield characteristics of rice varieties development in different years. Korean J. Crop Sci. **38** (4): 343-349.

Lin, Y., Zhu, Z.Q., Hu, J.Q., Pei, S.W.and Yeh, J.C. 1959. Studies on the prediction of the outbreak of the paddy borer, *Schoenobius incertellus* Walker, with effective thermal summation. I. The minimum temperature of development and effective thermal summations. Acta Entomol. Sin. **9**: 423-435.

Lippold, P.C. 1971. Rice pests, diseases and varietal resistance trials in East Pakistan. Ford Foundation, Lahore, Pakistan. 72 p.

Lippold, P.C. and Karim, A.N.M.R. 1970. Report of East Pakistan Accelerated Rice Research Programme. Annual Report of Entomology Division. 78 p.

Lu, X., Kumg, F., Li, X. Xiao, F. and Luo, Z. 1992. Physiological factors for high proportion of empty-unfilled grains in two-line intersubspecies Hybrid rice. J. Human Agril. Coll. **18** (3):509-515.

Lukefahr, M.J., Martin, D.F. and Mayer, J.R. 1965. Plant resistance to five Lepidopterans attacking cotton. J.Econ. Ent. **58**: 516-518.

Malhi, B.S. and Brar, D.S., 1998. Biology of yellow stem borer, *Scirpophaga incertulas* Walker on Basmati rice. *J. Insect Sci.*, **11**: 27-129.

Mallik, S.N. and Behera, P.E. 1965. Incidence of the gall fly and stern borer *(Schenobius incertulas* Walk.) in relation to its time of planting and age of the crop. Rice Comm. Newsl. **15** (3): 76-80.

Mandel, B.K., Mandel, B.B. and Datta, B. 1990. Performance of inter varietal intercropping on rice in summer. Indian J. Agron. **105**: 508-514.

Manickavasagar, P., and Miyashita, K. 1959. The status of the paddy stem borer. *Schoenobius incertulas* Walker in Southeast Asia. Trop. Agr., Ceylon, **115**: 69-84.

Manna, R.A. 1987. Organic and inorganic fertilization studies under different rice planting geometry in lowland cropping systems. Coll. Laguna, Philippines.122 p.

Mannan, M.A. 1996. A study on the effect of fertilization on grain yield and quality of transplant aman rice. M.S. Thesis, Dept. Agron. Bangladesh Agril. Univ., Mymensingh.

Manwan, I. and Vega, C.R. 1975. Resistance of rice varieties to yellow borer. *Tryporyza incertulas* (Walker): Paper presented at IRRI, Saturday Seminar, May 10, 1975. Int Rice Res. Int., Los Banos, the Philippines. 37 p.

Marwat, N.K., Baloch, U.K. and Latif, A. 1985. Resistance of some new rice cultivars against the attack of *Tryporyza spp* stem borers. Pakistan J. Zool. **17** (4): 357-361.

Matsuo, T. 1952. Genecological studies on the cultivated rice ll. Varietal difference on damages by the rice stem borer (in Japanese). Bull. natl. Inst. Agric. Sci. D. Ho. **3**: 30-39.

Maxwell, F.G. 1972. Host plant resistance to insects-nutritional and pest management relationships. In: Insect and mite nutrition (ed. J.G. Rodriguez). Amsterdam, North-Holland. 599-609 pp.

McNaughton, E.J. 1946. World paddy pests, their nature, distribution, importance and control with special reference to "Gammexane". Cent. Agric. Contr., ICI. London, U.K. 500p.

Medrano,F.G. and Heinrichs,E.A.1985. A simple technique of rearing of yellow stem borer, *Scirpophaga incertulas* (Walker).Int.Rice Res.Newsl.**10** (4):14-14

Mia, M.A.B. 1993. Morpho-physiological studies of some rice cultivars. M.Sc. (Ag.) Thesis. Dept. Crop Bot. Bangladesh Agril. Univ., Mymensingh. 29 p.

Miah, M.N.H., Yoshida, T., Yamamoto, Y. and Nitta, Y. 1996. Characteristics of dry matter production and partitioning of dry matter to panicles in high yielding semi-dwarf *indica* and *japonica* hybrid rice varieties. Japanese J. Crop Sci. **65** (40): 672–685.

Mishra, M.K., Sharma, R.C., Singh, R.B. and Singh, R.P. 2012. Monitoring of yellow stem borer, *Scirpophaga incertulas* Walker in rice through light and pheromone traps. Agric. & Biological Res., **28** (2): 135-139

Moiz, S.A. 1967. Ecology of the rice stem borer, *Tryporyza incertulas* (Walker) in West Pakistan, preliminary studies. Proc. Joint F.A.O. I.A.E.A., Vienna [R.A.E. 58: 923]

Motomatsu, T., Takebe, M. and Yoneyama, T. 1990. Physiological characteristics of high yielding rice varieties: dry matter production and nutrient uptake. Japanese J. Crop Sci. **60** (5): 248.

Munakata, K. and Okamoto, D. 1967. Varietal resistance to rice stem borers in Japan. *In:* Major Insect Pests of Rice Plant. Johns Hopkins University Press, Baltimore, Maryland. 419-430 pp.

Munakata, K., Saito, T., Ogawa, S. and Ishii, S. 1959. Oryzanone an attractant to the rice stem borer, Bull. Agric. Chern. Soc. Jap. **23** (1): 64-65.

Munoz, R.K. and Betancourt, D. 1992. Hybrid rice research in Colombia. Arroz. **41** (379): 20-28. [CAB Abst. 1993-1994].

Murty, K.S., Pattanaik, R.K. and Swain, P. 1986. Net assimilation rate and its related plant characters of high yielding rice varieties. Indian J. Plant Physiol. **29** (1): 53-60.

Naher, Q. 1995. Growth and Yield of Two Modern Rice Varieties under Year Round Transplanting. M.S. Thesis. Dept. Agron, Bangladesh Agril. Univ. Mymensingh.31-56 pp.

Nakano, K., Abe, G., Taketa, N. and Hirano, C. 1961. Silicon as an insect resistance component of host plant, found in the relation between the rice stem borer and rice plant (in Japanese with English Summary). Jap. J. Appl. Ent. Zool. **5**: l7-27.

Nishida, T. and Torri, T. 1970. A hand book of field methods for research on rice stem borers and their natural enemies. International Biological Programme. Hand book No.14, Black Wells, Science Publication, Oxford and Edinburgh. 132 p.

Nozato, K. 1982a. Influence of group size and growth stage of rice on survival of hatched larvae of *Chilo suppressalis* Walk. (Lepidoptera: Pyralidae). Jap. J. Appl. Ent. Zool. **26** (1): 63-67.

Nozato, K. 1982b. Effect of group size on larval survival of *chilo suppressalis* Walk. (Lepidoptera: Pyralidae). Jap. J. Appl. Ent. Zool. **26** (2): 119-124.

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshida, T. and Miyazaki, A. 2000. Varietal difference in tillering ability of fourteen *Japonica* and *indica* rice varieties. Soil Sci. and Plant Nutri. **46** (2): 381-391.

Okamoto, D. and Abe, Y. 1958. Varietal differences in rice stem borer infestation of rice. Nagoya Engei (Agric. Hort.). **33**: 58-59.

Oliver, B.F., Gifford, J.R.1975. Weight differences among stalk borer larvae collected from rice lines showing resistance in field studies. J. Econ. Ent. **68** (1): 134.

Onate, B.T. 1965. Estimation of stem borer damage in rice fields. Phil. Stat. **14:** 201-221.

Otanes, F.Q. and Sison, P. 1952. Pest of rice. Dept. Agric. Natural. Resour. , Pop. Bull. No.42. 10-16 pp.

Padhi, G and Saha, S. 2004. Influence of weather parameter on population fluctuation of rice yellow stem borer *(Scirpophoga incertulas* Walker) in light trap catches. Environ. & Ecol., **22** (3): 504-507.

Padhi, G. and Chatterji, S.M. 1984. Oviposition preference of *Scirpophaga (Tryporyza) incertulas* (Walk.) on different varieties of rice under caged conditions. J. Ent. Res. **8** (1): 81-85.

Padhi, G. and Chatterji, S.M. 1986. Influence of nitrogen in rice varieties on the yellow stem borer *(Scirpophaga incertulas* Walk.) infestation. J. Entom. Res. **10** (2): 171-173.

Padhi, G. and Prakasa Rao, R.S. 1978. Preliminary studies on reaction of some wild rices to infestation by the yellow rice stem borer, *Tryporyza incertulas* Walker. Oryza. **15**: 99-101.

Padilla, M.J. 1966. Mating habits and sex attractions in striped rice borer, *Chilo suppressalis* Walk. MS Thesis, University of the Philippines, Los Banos, Laguna, the Philippines. 92p.

Pagden, H. 1930. A preliminary account of three rice stem borers. Straits settlement Feb. Malaya States. Dept. Agric. Sci. Ser. Bull. No.1. 30 p.

Painter, R.H. 1951. Insect Resistance in Crop Plants. Mcmillan, New York. 520 p.

Panda, N. 1979. Principles of Host-Plant Resistance to Insect Pests. Hindustan publishing Corporation (India), Delhi. 386p.

Panda, N., Pradhan, B., Sarnalo, A.P., Prakasa Rao, P.S. 1975. Note on the relationship of some biochemical factors with the resistance in rice varieties to yellow rice borer Indian J. Agric. Sci. **45**: 499-501.

Panda, N., Sarnalo, A.P., Patra, N.C. and Reddy, T.G. 1973. Survival and development of the larvae of yellow rice borer, *Tryporyza incertulas* Walk. (Lepidoptera: Pyralidae), on resistant and susceptible rice varieties. Indian J. Agric. Sci. **43** (9): 879-881.

Pandey, R.K., and Singh, V.B. 1980. Vegetative growth and drymatter production and seed yield of field pea (*Pisum sativum* L. Arvens), Legume Res**. 3**: 1-6.

Pans Manual No.3. 1976. Pest Control in Rice. Second Edition. Centre for Overseas Pest Research, London, U.K. 295 p.

Paranhos, J.T., Marchengan, E. and Dutra, L.M.C. 1995. Dry matter accumulation in three cultivars of irrigated rice with different plant canopy structure. Ciencia Rural. **25** (1): 55-60. [Rice Abst. 1996. 2: 75].

Paranhos, J.T., Marchezan, E. and Tutra, L.M.C. 1997. Morphological parameters of three irrigated rice varieties. Intl. Rice Res. Newsl., **17** (5):9.

Parwez, A., Mandal, S. K., Sattar, A. and Mishra, A.K. 2006. Population dynamics of stem borer, *Scirpophaga incertulas* Walker and spider in boro rice: a bio meteorological interaction study. *Environ. & Ecol:* **24** (1) 152-154.

Parwez, A., Misra, A.K., Mandal, S.K. and Sattar, A. 2005. Activity of *Scirpophaga incertulas* and *Lycosa Pseudoannulata* in boro rice as influenced by meteorological parameters. J. Appl. Biol. **15** (2): 55-59.

Patanakamjorn, S. and Pathak, M.D. 1967. Varietal resistance of Asiatic rice borer, *Chilo suppressalis* Walker in rice and its association with various plant characters. Ann. ent. Soc. Am. **60**: 287-292.

Pathak, M.D. 1964. Varietal resistance as a method of rice stem borer contro1. Int. Rice Comm. Newsl. **13**: 15-21.

Pathak, M.D. 1967a. Recent developments and future prospects for the chemical control of the stem borer at IRRI. In: The major insect pests of rice plant. 335-349 pp.

Pathak, M.D. 1967b. Varietal resistance to rice stem borers at IRRI. In*:* The Major Insect Pests of the Rice Plants. Proceeding of a symposium at the International Rice

Research Institute, Sept. 1964. Johns Hopkins Press, Baltimore, Maryland. 405-418 pp.

Pathak, M.D. 1968. Ecology of common insect pests of rice. Ann. Rev. Ent. **13**: 257-294.

Pathak, M.D. 1969a. Integrated control of rice stem borers, leafhoppers and planthoppers. Paper presented at the International Rice Research Conference, Apr. 1969.International Rice Research Institute, Los Banos, the Philippines. 15 p.

Pathak, M.D. 1969b. Stem borer and leafhopper-planthopper resistance in rice varieties. Entomol. Exp.Appl. **12** (5): 789-800.

Pathak, M.D. 1970. Genetics of plant resistance in pest management. In: Rabb, R.L. and Guthrie, P.E. (eds.) Concept of Pest Management, N.C. State. Univ., Raleigh. 138-157 pp.

Pathak, M.D. 1971. Resistance to leaf hoppers and plant hoppers in rice varieties. In*: Symposium on rice insects.* July 1971. Tropical Agricultural Research Center, Tokyo, Japan. 179-193 pp.

Pathak, M.D. 1975. Utilization of insect-plant interrelationships in pest control. In: Pimental, D. (Ed.) Insect Science and Society. Academic Press, London and New York. 121-148 pp.

Pathak, M.D. 1977. Defense of the rice crop against insect pests.. In: Proceeding of a symposium on the genetic basis of epidemics in agriculture, Day, P.R., ed., Ann. New York Acad. Sci., USA. 287-295 pp.

Pathak, M.D. and Dale, D. 1983. The biochemical basis of resistance in host plants to insect pests. In: Chemistry and World Supplies. The New Frontiers, Chemrawn II (ed. L.W. Shemilt) Pergamon Press, Oxford, New York. 664 p.

Pathak, M.D., Andres, F., Galacgac, N., Raros, R. 1971. Resistance of rice varieties to Striped Rice borers. Int. Rice Res. Inst. Tech. Bull. 11. 35-69 pp.

Pawar, M.S., Reddy, V., Rajagopalan, K. and Suryanarayana Murthy, V.V. 1959. Scope for breeding rice varieties to major pests. In: Proc. Rice Res. Workers Conf. Cuttack, India. 304-305 pp.

Prakasa Rao, P.S. 1972. Nature of stem borer *(Tryporyza incertulas* Walk.) resistance in rice. Summary of results presented to the research council, Central Rice Research Institute (CRRI), India, May 19, 1972. 4 p.

Prakasa Rao, P.S. 1983a. Ecology of the yellow rice borer. Effect of climate and season In: Proc. Sym. Ins. Ecol. and Resource Manage. Goel, S.C., Ed., Sanatan Dharm College, Muzaffarnagar, India. 28-37 pp.

Prakasa Rao, P.S. 1983b. Sources and nature of resistance to the yellow rice borer, *Scirpophaga incertulas* Walk. In rice. Proc. Rice Pest Management Seminar. Chel1iah, S. and Balasubramanian, M., eds., Tamil Nadu Agricultural University, Coimbatore, India. 199-210 pp.

Prakasa Rao, P.S., Seshagiri Rao, Y. and Israel,P. 1971. Factors favouring incidence of rice pests and methods of forecasting outbreaks of gall midge and stern borers. *Oryza.* **8** (2): 336-358.

Price, P. W. 1998. An overview of organismal interactions in ecosystems in evolutionary and ecological time. Agriculture, Ecosystems and Environment. **24**: 369-377.

Pruneddu, G. and Spanu, A. 2001. Varietal comparison of rice in Sardinia Dipertimentoid Science Agronomic Genetica Vegetable Agaria, Universita degli, Italy. Informatore-Agrario, **57** (5):47-49. [Rice. Abst. 2002. (4): 85].

Puttarudriah, M. 1945. Some observations made on the biology, habits, and control of the paddy stem borer, *Schoenobius incertulas* (Waker). Mysore Agric. J. **24**: *167*

Rafey, A., Khan, P.A. and Srivastava, V.C. 1989. Effect of N on growth, yield and nutrient uptake of upland rice. Indian J. Agron. **34** (2): 133-135.

Rahman, M. T., Khalequzzaman, M. and Khan, M.A.R. 2004. Assessment of infestation and yield loss by stem borers on variety of rice. J. Asia-Pacific Entomol., **7** (1): 89-95.

Rahman, M.S. 1991. Growth characteristics and agronomic performance of some early and late maturing rice cultivars under irrigated lowland, rainfed lowland and upland cultural condition, Ph.D. thesis. 46 p.

Rao, V.P. 1964. Survey for natural enemies of pests of paddy. PL-480 Project. Final Technical Report, 1961-1964, CIBC, Indian Station, Bangalore. 37 p.

Razvi, S.A. 1991. Bio-ecology and management of rice yellow stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Pyralidae). Ph.D. Thesis, Andhra Pradesh Agricultural University, Hyderabad, A.P. India.

Reddy, Y.A.N., Prasad, T.G. and Udaya Kumar, M. 1995. Relationship between leaf area index, specific leaf weight and assimilation rate in rice genotypes. Madras Agril. J**.** **82** (11): 616-617.

Reddy, Y.A.N., Prasad, T.G., Kumar, M.U. and Sharker, R.U. 1994. Selection for high assimilation efficiency. An approach to improve productivity in rice. Indian J. Plant Physio. **37** (2): 133-135.

Rothschild, G.H.L. 1971. The biology and ecology of rice stern borer in Sarawak (Malaysian Borneo). J. Appl.EcoI.**8** (2): 287-322.

Saha, N.N. and Saharia, D. 1970. Effects of dates of transplanting and levels of nitrogen on the incidence of stern borer, *Tryporyza incertulas* (Walk.) in paddy in Assam. Indian J. Ent **32** (3): 225-229.

Sahu, S.K. and Mohapatra, P.K. 1992. Metabolic contents and panicle development in indica rice varieties belonging to different growth duration groups. Australian J. Plant Physio. **10** (2): 185-192.

Saito, K., Shimoda, H. and Ishihara, K. 1990. Characteristics of dry matter production in high yielding rice cultivars. II. Comparison among two early and three medium cultivars. Japanese J. Crop Sci. **59** (2): 303-311.

Saito, T. 1975. Application of insecticide for the control of stem borers in South East Asia. Rice in Asia, University of Tokyo Press.400-41l pp.

Salam, M.A. Moniruzzaman, A.F.M. and Chowdhury, S.I. 1987. Growth analysis in mungbean.Bangladesh J.Nucl.Agric.**3**:58-64

Salam, M.A., Khurshed, A. and Chowdhury, S.I. 1990. Morpho-physiological aspects of Binasail for its improved yield potential over the parent Nizersail. Bangladesh J. Nucl. Agric. **5** (5): 15-21.

Saroja, R. and Raju, N. 1981. Varietal reaction to rice stem borer under different nitrogen levels. Int. Rice Res. Newsl. **6**: 7.

Saxena, R.C. 1978. Biochemical basis of resistance in crop plants. Saturday Seminar, International Rice Research Institute. Los Banos. Laguna, the Philippines, 11 March. 25 p.

Saxena, R.C., Medrano, F.G. and Sunio, L. M., 1990. Rearing yellow stem borer (YSB) for screening varietal resistance. International Rice Research Newsl. **15**:15.

Seko, H. and Kato, 1. 1950. Studies on the resistance of rice plant against the attack of rice stem *borer, Chilo simplex.* Butler. I. Inter-relation between plant character and frequency of egg laying in the first generation of rice stem borer (Prelim. report) [In Japanese, English Summary]. Proc. Crop Sci. Soc. Jap. **19**: 201-203.

Shamsuddin, A.M. Islam, M.A. and Hossain, A. 1988. Comparative study on the yield and agronomic characters of nine cultivars of aus rice. Bangladesh J. Agril. Sci. **15** (1): 121-124.

Shi, Q.H. and Akita, S. 1993. Potential dry matter production and grain yield of present rice cultivars in the tropics. Acta Argil. Univ. Jiangxensis. **15** (2): 129-137. [Rice Abst. 1994. 18(1)].

Shiraki, T. 1917. Paddy borer, *Schoenobius incertulass* Walk. Taihoku Agric. Expt. Stat. Govt. Formosa, Taihoku. 256 p.

Singh, K.G. and Soenardi, M. 1973. Insect pests of rice in Java, Indonesia. Int. Rice Comm. Newsl. **22**: 22-25.

Singh, R., Mahal, M.S. and Kajal, V.K. 2006. Influence of pheromone traps in management of yellow stem borer, *Scirpophaga incertulas* Walker on basmati rice. J. Insect Sci ., **19** (1) 22-26.

Singh, S. and Gangwer, B. 1989. Comparative studies on production potentials in traditional tall and improved rice cultivars. J. Andaman Sci. Assoc. **5** (1): 81-82. .

Slama, K., 1969. Plant as a source of materials with insect hormone activity. Ent. Exp. & Appl. **12**: 721-728.

Slama, K., 1979. Insect hormones and anti-hormones in plants. Herbivores: Their Interaction with Secondary Plant Metabolites. Academic. Press, New York.

Soehardjan, M. 1974. Strategy for rice stem borer research in Indonesia. Paper presented at the NRRP Meeting, February 14, 1974. Indonesia, 8 p.

Soehardjan, M., Soekama, D. and Leeuwangh, J. 1974. Stem borer and gall midge infestation at different growth stages of the rice plant under field conditions. In: Agricultural Cooperation, Indonesia. The Netherlands, Jakarta, Indonesia Research Reports. 1968-1974. Section II. Bogor. Ministry of Agriculture, Jakarta, Indonesia. 126-130 pp.

Soenardi, J. 1967. Insect pests of rice in Indonesia. In: Major Insect Pests of the Rice Plant. Johns Hopkins University Press, Baltimore, Maryland. 675-683 pp

Southwood, T.R.E. 1966. Ecological methods with particular reference to the study of insect populations. Methuen, London. 391 p.

Srivastava, G.K. and Tripathi, R.S., 1998. Correlation between yield and its components in upland rice in Cuba. Intl. Rice Res. Newsl. **14**: 3.

Suoez, E., Alfonso, R.K., Perez, R. and Iglesias, J. 1989. Correlation between yield and its components in upland rice in Caba. Intl. Rice Res. Newsl. **14** (3): 231.

Suprihatno, B. and Sutaryo, B. 1992. Yield performance of some new rice hybrids in Indonesia. Intl. Rice Res. News. **17** (3): 12.

Swaint, P., Pattanaik, R.K., Nayak, S.K. and Murty, K.S. 1986. Relationship between photosynthetic rate, growth components and yield in elite rice varieties. J. Nuclear Agric. & Boil. **5** (1): 18-22.

Takami, S. 1990. The increase in dry matter and yield in rice and relation to the catapult process of growth. Korean J. Crop Sci**. 35** (3): 153.

Torri, T. 1971. The ecological studies of rice stem borers in Japan, a review. Mushi **45** (1): 1-49.

Tripathy, M.K. and Kanungo, A.P. 2008. Demonstration of integrated pest management technology in rice at farmer's fields. J. Plant Protec. & Environ., **5** (1): 30-33.

Tsai, J.C. 1984. Studies on the relationship between leaf area index and yield in rice plants. J. Agril. Res. China. **33** (2): 109-116.

Tsai, J.C. 1991. Principal component analysis and variety classification in relation to regional and seasonal differences in grain yield and physiological characteristics in rice. J. Agril. Res. China. **40** (3): 315-332.

Tsou, T.L. 1947. A study on the problem of double crop system of rice in relation to the infestation of the rice stem borer in eastern Szenchawan *[In* Chinese, English summary]. 1. Agric. Assoc. China. **184:** 27-38.

Tsutsui, K. 1951. Bionomics of the rice stem borer and the resistance of the rice plant to the borer. Agric. Tech. **6** (2): 40-43.

Tsutsui, K., Sato, A., Tanaka, K., Tanimoto, S. and Onozi, S. 1957. Studies on the fluctuation of outbreak of the rice stern borer (*Chilo suppressalis* Walk.) on the paddy rice plant transplanted in early and late period *(In* Japanese, English Summary]. Bull. Div. Plant Breed. Cultiv. Tokai Kinki natl. Agric. Exp. Stat. No.4105-120 pp.

Uddin, M.I. and Azim, M.A. 1998. Correlation and path analysis studies for yield related traits in rainfed rice. Bangladesh J. Nuclear Agric. **14**: 15-19.

Van Der Goot, P. 1925. Life history and control of the white rice stem borer in Java [In Dutch, English Summary]. Meded. Inst. PLziekt. Buitenzorg. No. 66. 308 p.

Van Der Goot, P. 1948a. Twelve years of rice borer control by regulating the time of sowing in West Brebes, Central Java (In Dutch, English Summary). Meded Alg. Proefst, Landb. Buitenzorg No. 78. 12p.

Van Der Goot, P. 1948b. Levenswizze van de gele riwstboorder (The life history of the yellow rice borer) Meded alg. Proefst. Landb., Buitenzorg, No. 79. 12 p. I*n* Dutch

English summary]; also in Landbouw, Buitenzorg **20** (11-12): 495-504. [R.A.E. (A) **40:** 1952].

Varma, N.R.G, Krishnaiah, K., Pasalu, I.C. and Rao, P.R.M. 2004. Influence offield size in management of yellow stem borer (YSB), *Scirpophaga incertulas* Walker through pheromone mediated mass trapping in rice. Indian J. Plant Pro tee. **32 (1):** 39-41.

Varma, N.R.G., Krishnaiah, K., Pasalu, I.C. and Reddy, D.D.R. 2000. Monitoring of rice yellow stem borer, *Scirpophaga incertulas* Walker using pheromone traps and thermal summations. Indian J. Plant Protec., **28** (1): 84-93.

Vergara, B.S., Lilis, R. and Tanaka, A. 1964. Relationship between length of growing period and yield of rice plants under a limited nitrogen supply. Soil Sci. and Plant Nutrition. **10:** 59-65.

Viajante, V.D. and Saxena, R.C. 1988. Effect of plant age on rice susceptibility to yellow stem borer (YSB), *Scirpophaga incertulas* (Walk.). lnt. Rice Res. Newsl. **13** (3): 37.

Wada, E. 1942. On some characteristics of rice varieties of Southern Asia. Kagaku Sci. **12**(11): 441-444.

Watson, D.J. 1978. The physiological basis of variation in yield. Adv. Agron. **4**: 1401-1452.

Weing, J.H. and Chen, C.V., 1988. Photosynthesis, dry matter production and grain yield of rice. IV. The relationship between CGR and LAI. J. Agric. Assoc. China. **143**: 38-47.

Wong, Y., Kuroda, E., Hirano, M., Murak, T. and Wang, Y.D. 1997. Comparison of growth and yield characteristics and dry matter production. Japanese J. Crop Sci. **66** (2): 293–299.

Yadava, M.S., Bana, O.P.S. and Singh, M. 1988. Vegetative characters limiting yield in rice genotypes. Indian J. Bot. **11** (1): 74-81.

Yang, J., Zhu, Q., Wang, Z. and lang, Y. 1997. Photosynthetic characteristics, dry matter accumulation and its transplantation in inter-specific hybrid rice. Acta Agronomoca Sinicia. **23** (1): 82-88.

Yasumatsu, K. 1972. Activities, scope and problems in rice stem borer research. Mushi **45**: 3-6.

Yoshida, S. 1981. Fundamentals of Rice Crop Science. Intl. Rice Res. Inst. Los Banos, Philippines.269 p.

Yoshida, T., Miyazaki, A., Nuruzzaman, M., Nitta, Y. 1999. Varietal difference in tillering ability of fourteen *Japonica* and *Indica* rice varieties. Soil Sci. and Plant Nutri. **46** (20): 381-391.

Yuan, L.P. and Fu, X.Q. 1995. Technology of Hybrid Rice Production. Food Agric. Orga. Rome.2-4 pp.

Yunus, A. 1967. Insect pests of rice in Malaysia. Part 1. Malayan Region. In: The Major Insect Pests of the Rice Plants. Johns Hopkins Press, Baltimore, Maryland, USA. 617-633 pp.

Zafar, M.A. 1983. Effect of rice stubble on stem borer hibernation. Int. Rice Res. Newsl. **8** (6): 16.

Zaheruddin, S.M. and Prakasa Rao, P.S. 1983. *Leptochloa panicoides* Wight, an occasional host of the yellow rice borer, *Scirpophaga incertulas* Walker. Int. Rice Res. Newsl. **8** (4):17-18.

CHAPTER 7

APPENDICES

Appendix I. Physico-chemical properties of the experimental soil (0-15 cm depth)

Constituents	Results
Physical properties	
Sand (0.2-0.02 mm)	24.10%
Silt (0.02-0.002 mm)	69.25%
Clay (<0.0002 mm)	12.20%
Textural class	Silt loam
Chemical compsition	
pH	6.02
Organic matter	1.72%
Total nitrogen	0.178%
Available phosporus	35.44 ppm
Available sulphur	12.52 ppm
Exchangeable potassium	0.07 m.e. 100^{-1} g soil
Available zinc	3.86ppm

Source: Department of Soil Science, Bangabandhu Sheikh Mojibur Rahman Agricultural University (BSMRAU), Gazipur

Appendix II. Monthly average of weather records of the experimental site during the study period (2010)

Month	**Air Temperature (°C)			**Soil Temperature (°C), Depth			**Humidity (%)	*Rain Fall (mm)	*Evaporation (mm)	**Ground water table (m)
	Max.	Min.	Ave.	10 cm.	20 cm.	30 cm				
January	15.20	11.58	13.39	16.90	17.33	17.72	90.80	00.0	40.28	16.84
February	23.85	19.08	21.47	20.85	21.30	21.66	89.89	8.43	57.77	17.97
March	31.16	26.09	28.62	22.71	23.22	23.59	76.70	29.84	93.8	19.04
April	32.13	28.2	30.16	27.85	28.38	28.88	76.53	57.11	94.75	19.32
May	31.40	27.90	26.65	28.5	29.01	29.53	82.0	252.23	85.58	18.70
June	32.06	29.26	30.66	29.15	29.63	30.05	85.96	369.53	72.57	18.31
July	32.32	27.67	30.0	29.06	29.58	30.0	83.45	269.13	80.83	18.13
August	32.0	25.90	28.95	29.31	29.80	30.12	85.58	138.65	28.42	18.09
September	30.38	26.53	28.45	29.31	29.76	30.15	89.46	212.65	50.09	17.05
October	30.67	27.06	28.87	29.29	29.77	30.19	87.41	187.01	52.58	16.93
November	27.76	23.76	25.76	26.55	26.91	27.33	85.66	00.0	55.06	17.56
December	24.80	16.58	20.69	22.72	23.17	23.56	90.70	55.19	208.15	17.32
Ave./total	29.46	24.81	27.14	26.73	27.62	27.61	85.34	1579.77	919.88	17.93

Source: Weather station, Department of Agricultural Engineering, BSMRAU
*Monthly total, **Monthly average

Appendix II. (Cont'd) Monthly average of weather records of the experimental site during the study period (2011)

Month	**Air Temperature (ºC)			**Soil Temperature (ºC), Depth			**Humidity (%)	*Rain Fall (mm)	*Evaporation (mm)	**Ground water table (m)
	Max.	Min.	Ave.	10 cm.	20 cm.	30 cm				
January	19.5	10.3	14.9	18.7	19.1	19.6	90.2	0.00	48.10	18.35
February	27.0	15.4	21.2	21.3	21.7	21.9	88.4	0.00	77.30	19.32
March	31.0	25.5	28.4	24.5	24.8	25.1	86.0	105.2	108.50	20.31
April	32.5	28.1	30.3	26.3	26.7	27.1	87.6	117.10	97.20	19.52
May	33.0	28.5	30.8	27.0	27.4	27.8	86.9	234.30	90.90	19.36
June	32.6	29.0	30.8	28.6	29.0	29.4	88.7	344.60	78.60	18.91
July	31.8	27.0	29.4	29.3	29.7	30.1	90.0	429.20	78.40	19.07
August	32.5	26.3	29.4	29.3	29.8	30.1	85.3	267.80	82.40	18.62
September	32.4	26.3	29.3	29.7	29.7	29.9	83.4	176.50	89.20	18.30
October	31.4	26.2	28.8	28.8	29.3	29.7	85.5	10.10	86.3	18.10
November	27.5	23.4	25.4	26.4	26.8	27.1	85.7	0.00	55.10	18.62
December	23.0	13.4	18.2	22.1	23.0	23.4	79.4	0.00	44.58	18.98
Ave./total	29.5	23.3	26.4	26.0	26.4	26.7	86.4	1684.8	936.58	18.96

Source: Weather station, Department of Agricultural Engineering, BSMRAU
*Monthly total, **Monthly average

Appendix II. (Cont'd) Monthly average of weather records of the experimental site during the study period (2012)

Month	**Air Temperature (ºC)			**Soil Temperature (ºC), Depth			**Humidity (%)	*Rain Fall (mm)	*Evaporation (mm)	**Ground water table (m)
	Max.	Min.	Ave.	10 cm.	20 cm.	30 cm				
January	22.5	11.7	17.1	19.0	19.5	19.9	87.9	9.20	46.50	19.45
February	27.3	13.6	20.4	20.0	20.4	20.9	88.9	0.00	104.15	20.30
March	31.9	20.8	26.3	23.5	24.0	24.4	86.4	1.62	135.19	21.10
April	34.2	23.1	28.7	25.8	26.2	26.7	86.9	148.00	140.00	20.95
May	34.3	25.3	29.8	28.1	28.5	28.8	85.3	143.76	122.43	20.55
June	32.8	26.1	29.4	30.2	30.7	30.9	86.7	167.00	110.30	20.19
July	31.9	27.1	29.5	29.2	29.5	30.0	90.4	334.56	83.69	20.07
August	31.1	25.7	28.4	29.4	29.8	30.2	87.0	184.23	76.17	19.96
September	33.2	26.7	30.0	29.3	29.6	30.0	84.0	74.48	85.81	20.10
October	31.7	22.5	27.1	29.2	29.5	30.0	85.0	78.87	79.93	20.05
November	28.6	17.5	23.0	24.5	24.9	25.2	77.7	75.96	65.59	19.79
December	23.5	12.9	18.2	20.9	21.3	21.6	84.7	2.43	37.51	20.16
Ave./total	30.3	21.1	25.7	25.8	26.2	26.6	85.90	1220.11	1087.27	20.22

Source: Weather station, Department of Agricultural Engineering, BSMRAU
*Monthly total, **Monthly average

Appendix II. (Cont'd) Monthly average of weather records of the experimental site during the study period (2013)

Month	**Air Temperature (ºC)			**Soil Temperature (ºC), Depth			**Dry/Wet bulb Temp. (ºC) at 9am		**Humidity	*Rain Fall	*Evaporation	Atmospheric pressure	**Ground water table
	Max.	Min.	Ave.	10 cm.	20 cm.	30 cm	Dry	Wet	(%)	(mm)	(mm)	(inHg)	(m)
January	23.67	9.74	16.70	18.43	18.38	18.30	-	-	83.41	00.00	54.31	-	20.65
February	28.25	15.25	21.75	20.96	20.94	21.01	-	-	71.25	09.74	89.01	-	21.33
March	32.79	19.98	26.38	23.95	24.11	24.22	-	-	71.22	15.90	125.71	-	21.73
April	33.83	23.1	28.46	27.76	28.38	28.85	29.0	27.0	75.36	85.69	124.74	29.96	22.54
May	31.15	24.22	27.69	28.29	28.70	28.85	27.74	25.41	82.38	421.03	102.13	29.82	21.58
June	33.53	27.38	30.45	31.15	30.96	31.23	30.76	28.31	82.10	340.35	109.29	29.74	21.35
July	32.59	26.95	29.77	32.35	30.98	30.95	29.43	27.37	83.45	163.72	120.99	29.66	21.55
August	31.64	26.43	29.04	32.17	29.82	30.03	28.87	26.93	85.29	178.16	97.64	29.64	21.40
September	31.96	26.41	29.18	32.31	30.53	30.02	29.16	27.43	86.7	151.08	97.48	29.78	21.35
October	30.79	24.72	27.75	31.86	28.86	28.41	27.85	25.67	84.41	219.67	82.52	29.85	21.17
November	28.84	15.66	22.25	27.56	24.95	24.25	24.48	21.5	78.0	00.00	72.29	30.10	21.21
December	26.39	13.00	19.7	22.38	20.95	20.35	19.45	17.69	82.06	01.62	58.82	30.12	21.49
Ave./total	30.45	21.07	25.76	27.43	26.46	26.37	27.41	25.25	80.46	1586.96	1134.93	29.85	21.44

Source: Weather station, Department of Agricultural Engineering, BSMRAU
*Monthly total, **Monthly average

Appendix II. (Cont'd) Monthly average of weather records of th`e experimental site during the study period (2014)

Month	**Air Temperature (ºC)**			**Soil Temperature (ºC), Depth**			**Dry/Wet bulb Temp. (ºC) at 9am**		**Humidity	*Rain Fall	*Evaporation	Atmospheric pressure	**Ground water table
	Max.	Min.	Ave.	10 cm.	20 cm.	30 cm	Dry	Wet	(%)	(mm)	(mm)	(inHg)	(m)
January	23.40	12.14	17.77	20.83	18.67	18.22	16.61	15.74	87.06	0.00	58.58	30.20	21.53
February	25.51	13.66	19.59	22.26	20.53	19.85	19.67	16.96	76.96	46.73	40.73	36.07	22.23
March	30.74	18.60	24.67	21.64	23.15	22.39	22.77	22.58	22.68	17.52	131.47	30.07	22.79
April	35.48	23.71	29.60	29.61	28.41	35.03	30.03	25.90	74.63	112.64	187.02	29.91	23.22
May	34.74	26.06	30.40	31.74	30.47	29.54	29.38	26.80	81.80	138.62	139.94	29.87	23.00
June	32.75	26.63	29.69	31.61	30.06	29.70	29.23	27.06	84.33	322.33	97.19	29.82	23.00
July	33.06	27.22	30.14	32.11	30.62	30.40	18.29	17.35	85.19	229.69	103.91	14.38	22.84
August	31.75	26.90	29.33	29.77	28.98	28.58	29.00	26.87	83.96	420.05	84.57	0.00	-
September	32.70	26.76	29.73	30.23	29.48	29.36	29.30	27.00	79.20	132.00	100.25	0.00	-
October	31.11	23.58	27.35	30.89	29.22	28.61	28.06	25.83	83.00	48.68	90.15	0.00	-
November	29.85	17.60	23.73	25.78	24.08	23.64	24.60	22.30	81.20	0.00	62.77	0.00	-
December	24.63	11.53	18.08	21.50	20.60	19.95	16.93	15.66	86.40	0.00	18.74	0.00	-
Ave./total	30.47	21.19	25.83	27.33	26.18	26.27	24.48	22.50	77.20	1462.26	1115.32	16.19	22.65

Source: Weather station, Department of Agricultural Engineering, BSMRAU
*Monthly total, **Monthly average

Appendix III. Summary of analysis of variance for total dry matter at different phenological stages of seven modern rice varieties in *boro* season

Source of variation	Degrees of freedom	Mean square			
		Total dry matter (g $hill^{-1}$)			
		Maximum tillering stage	Panicle initiation stage	Heading stage	Maturity stage
Replication	2	1.618	3.752	3.139	4.760
Variety	6	46.060**	51.536**	45.522**	48.508**
Error	12	2.325	4.617	4.851	5.111
CV (%)		5.45	6.73	5.39	4.61

** = Significant at 1% level of probability

Appendix IV. Summary of analysis of variance for leaf area index at different phenological stages of seven modern rice varieties in *boro* season

Source of variation	Degrees of freedom	Mean square			
		Leaf area index (LAI)			
		Maximum tillering stage	Panicle initiation stage	Heading stage	Maturity stage
Replication	2	0.009	0.047	0.078	0.015
Variety	6	0.391**	0.711**	0.888**	0.294**
Error	12	0.012	0.033	0.061	0.006
CV (%)		4.51	5.36	6.63	3.30

Appendix V. Summary of analysis of variance for crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) at different phenological stages of seven modern rice varieties in *boro* season

Source of variation	Degrees of feedom	Mean square								
		CGR (g m^{-2} d^{-1})			RGR (g m^{-2} d^{-1})			NAR (g m^{-2} d^{-1})		
		MTS-PIS	PIS-HS	HS-MS	MTS-PIS	PIS-HS	HS-MS	MTS-PIS	PIS-HS	HS-MS
Replication	2	0.129	0.610	0.856	0.0001	0.0001	0.0001	0.039	0.050	0.053
Variety	6	4.132**	37.200**	9.262**	0.0011**	0.0012**	0.0010**	1.519**	3.631**	3.221**
Error	12	0.120	0.646	0.587	0.0001	0.0001	0.0001	0.041	0.059	0.041
CV (%)		4.65	4.41	5.92	9.33	5.53	8.89	7.70	5.45	4.88

** = Significant at 1% level of probability

Appendix VI. Summary of analysis of variance for grain growth pattern and grain growth rate of top rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Source of variation	Degrees of feedom	Mean square								
		Single grain weight (mg)					Grain growth rate (mg grain^{-1} d^{-1})			
		10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
Replication	2	0.183	0.335	0.916	0.362	0.386	0.001	0.001	0.001	0.0010
Variety	6	21.468**	21.013**	15.656**	31.815**	47.342**	0.007**	0.015**	0.091**	0.0450**
Error	12	0.140	0.404	0.552	0.654	0.881	0.001	0.001	0.002	0.0001
CV (%)		3.73	4.17	3.37	3.00	3.20	4.04	3.29	6.69	5.68

** = Significant at 1% level of probability

Appendix VII. Summary of analysis of variance for grain growth pattern and grain growth rate of middle rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Source of variation	Degrees of feedom	Mean square								
		Single grain weight (mg)					Grain growth rate (mg grain^{-1} d^{-1})			
		10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
Replication	2	0.149	0.100	0.519	0.384	0.974	0.002	0.001	0.005	0.001
Variety	6	15.278**	18.132**	30.785**	31.031**	27.951**	0.013**	0.041**	0.003NS	0.006**
Error	12	0.155	0.143	0.635	0.562	1.276	0.001	0.002	0.002	0.001
CV (%)		5.84	3.12	4.25	3.32	4.41	4.12	4.85	8.02	7.18

** = Significant at 1% level of probability
NS = Not significant
DAH = Days after heading

Appendix VIII. Summary of analysis of variance for grain growth pattern and grain growth rate of lower rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Source of variation	Degrees of feedom	Mean square								
		Single grain weight (mg)					Grain growth rate (mg grain^{-1} d^{-1})			
		10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
Replication	2	0.216	0.144	0.930	0.852	0.789	0.001	0.002	0.001	0.001
Variety	6	7.373**	8.112**	25.300**	16.704**	15.138**	0.035**	0.105**	0.043**	0.014**
Error	12	0.164	0.132	0.629	0.852	0.850	0.001	0.003	0.001	0.001
CV (%)		7.33	3.47	4.55	4.16	3.85	4.94	5.92	4.47	10.01

** = Significant at 1% level of probability
NS = Not significant
DAH = Days after heading

Appendix IX. Summary of analysis of variance for yield and yield contributing characters of seven modern rice varieties in *boro* season

Source of variation	Degrees of freedom	Mean square											
		Plant height at maturity stage (cm)	No. of total tillers hill^{-1} at maturity stage	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of total spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled spikelets panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	17.135	0.100	0.263	0.598	53.643	15.65	1.225	1.386	0.303	0.178	0.614	4.979
Variety	6	92.687**	3.893**	4.107**	4.367**	868.62**	1463.13**	83.45**	17.35**	2.25**	1.39**	6.04**	21.06**
Error	12	17.926	0.245	0.279	0.702	54.894	15.82	1.572	1.229	0.290	0.165	0.568	2.309
CV (%)		4.07	4.74	6.04	3.38	5.36	3.56	4.76	5.42	8.73	5.48	5.55	3.36

** = Significant at 1% level of probability

Appendix X. Total dry matter $hill^{-1}$ at different phenological stages of seven modern rice varieties in *boro* season

Variety	Total dry matter (g $hill^{-1}$)			
	MTS	PIS	HS	MS
IRATOM24	25.09 bc	28.59 b	38.12 b	45.90 b
BINA dhan5	30.89 a	35.47 a	44.16 a	52.18 a
BINA dhan6	32.47 a	36.70 a	44.51 a	53.19 a
BRRI dhan28	26.48 b	30.29 b	39.50 b	47.69 b
BRRI dhan29	32.67 a	36.45 a	45.90 a	54.16 a
BRRI dhan36	23.50 c	26.88 b	35.89 b	44.12 b
BADC1	24.69 bc	29.10 b	38.14 b	46.25 b
Level of significance	**	**	**	**
$S_{\bar{x}}$	0.879	1.24	1.27	1.30
CV (%)	5.45	6.73	5.39	4.61

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage, MS = Maturity stage

Appendix XI. Leaf area index (LAI) at different phenological stages of seven modern rice varieties in *boro* season

Variety	Leaf area index (g $hill^{-1}$)			
	MTS	PIS	HS	MS
IRATOM24	2.120 d	2.650 c	3.140 de	2.250 de
BINA dhan5	2.790 ab	3.720 a	3.020 e	2.490 c
BINA dhan6	2.680 b	3.800 a	4.260 ab	2.740 b
BRRI dhan28	2.430 c	3.330 b	3.860 bc	2.360 cd
BRRI dhan29	2.980 a	4.010 a	4.500 a	2.930 a
BRRI dhan36	2.040 d	3.020 b	3.550 cd	2.080 f
BADCI	2.210 d	3.120 b	3.700 c	2.150 ef
Level of significance	**	**	**	**
$S_{\bar{x}}$	0.063	0.104	0.142	0.044
CV (%)	4.51	5.36	6.63	3.30

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage, MS = Maturity stage

Appendix XII. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) during different phenological periods of seven modern rice varieties in *boro* season

Variety	CGR (g m^{-2} d^{-1})			RGR (g m^{-2} d^{-1})			NAR (g m^{-2} d^{-1})		
	MTS-PIS	PIS-HS	HS-MS	MTS-PIS	PIS-HS	HS-MS	MTS-PIS	PIS-HS	HS-MS
IRATOM24	7.080 bc	17.11 c	12.75 b	0.034 a	0.039 bcd	0.019 a	3.010 b	4.110 c	3.610 c
BINA dhan5	6.730 cd	15.04 d	11.13 c	0.015 b	0.025 cd	0.012 b	1.680 d	3.040 e	3.480 cd
BINA dhan6	6.420 d	15.10 d	11.15 c	0.014 b	0.023 cd	0.013 b	2.100 c	3.860 cd	3.190 d
BRRI dhan28	9.180 a	19.72 b	14.20 a	0.037 a	0.042 bc	0.021 a	3.250 ab	5.400 b	4.970 b
BRRI dhan29	6.350 d	15.14 d	11.52 bc	0.014 b	0.021 d	0.011 b	1.900 cd	3.510 d	3.120 d
BRRI dhan36	7.530 b	22.02 a	14.30 a	0.050 a	0.067 a	0.021 a	3.020 b	5.330 b	5.327 ab
BADCI	8.980 a	23.43 a	15.50 a	0.045 a	0.051 ab	0.022 a	3.430 a	5.950 a	5.440 a
Level of significance	**	**	**	**	**	**	**	**	**
$S_{\bar{x}}$	0.200	0.464	0.442	0.005	0.005	0.0018	0.116	0.140	0.116
CV (%)	4.65	4.41	5.92	9.33	5.53	8.89	7.70	5.45	4.88

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

MTS = Maximum tillering stage, PIS = Panicle initiation stage, HS = Heading stage, MS = Maturity stage

Appendix XIII. Grain growth pattern and grain growth rate of top rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Variety	Single grain weight (mg)					Grain growth rate (mg grain^{-1} d^{-1})			
	10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
IRATOM24	8.510 d	13.91 cd	21.17 de	25.09 c	27.10 c	0.770ab	1.030 a	0.5700 d	0.2800 c
BINA dhan5	11.06 b	16.12 b	23.08 bc	26.95 b	29.15 b	0.710c	0.9900 ab	0.5500 d	0.3100 c
BINA dhan6	13.11 a	18.01 a	24.11 ab	31.42 a	34.25 a	0.690 c	0.8700 c	1.000 a	0.4400 b
BRRI dhan28	9.980 c	14.67 c	21.80 cd	25.89 bc	27.89 bc	0.670 c	1.010 ab	0.5800 d	0.2800 c
BRRI dhan29	13.47 a	19.10 a	25.26 a	31.48 a	35.36 a	0.800a	0.8700 c	0.8800 b	0.5500 a
BRRI dhan36	6.390 f	11.92 e	18.69 f	23.18 d	25.20 d	0.780 a	0.9567 b	0.6300 cd	0.2900 c
BADCI	7.800 e	12.88 de	20.16 e	24.87 c	26.17 cd	0.720bc	1.030 a	0.6700 c	0.1800 d
Level of significance	**	**	**	**	**	**	**	**	**
$S_{\bar{x}}$	0.216	0.367	0.429	0.466	0.541	0.018	0.018	0.025	0.018
CV (%)	3.73	4.17	3.37	3.00	3.20	4.04	3.29	6.69	5.68

** = Significant at 1% level of probability
In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.
NS = Not significant, DAH = Days after heading

Appendix XIV. Grain growth pattern and grain growth rate of middle rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Variety	Single grain weight (mg)					Grain growth rate (mg grain^{-1} d^{-1})			
	10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
IRATOM24	5.530 e	10.89 de	17.10 cd	20.80 c	24.12 bc	0.7600 bc	0.8767 c	0.520	0.4700 ab
BINA dhan5	7.810 c	12.78 c	18.96 b	23.20 b	26.03 b	0.700 de	0.8800 c	0.600	0.4000 cd
BINA dhan6	8.690 b	14.70 b	22.40 a	26.44 a	28.89 a	0.8500 a	1.090 a	0.570	0.3500 d
BRRI dhan28	6.500 d	11.19 d	18.26 bc	22.18 b	25.17 bc	0.6700 e	1.000 b	0.560	0.4200 abc
BRRI dhan29	10.11 a	15.90 a	23.47 a	27.05 a	30.22 a	0.8200 a	1.070 ab	0.510	0.4500 abc
BRRI dhan36	3.900 f	9.100 f	14.68 e	18.36 d	21.75 d	0.7400 cd	0.7900 d	0.520	0.4800 a
BADCI	4.580 f	10.28 e	16.22 d	20.20 c	23.08 cd	0.8100 ab	0.8400 cd	0.560	0.4100 bc
Level of significance	**	**	**	**	**	**	**	NS	**
$S_{\bar{x}}$	0.227	0.218	0.460	0.432	0.650	0.018	0.025	0.025	0.018
CV (%)	5.84	3.12	4.25	3.32	4.41	4.12	4.85	8.02	7.18

** = Significant at 1% level of probability, NS = Not significant
In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.
NS = Not significant
DAH = Days after heading

Appendix XV. Grain growth pattern and grain growth rate of lower rachis of the panicle during different days after heading of seven modern rice varieties in *boro* season

Variety	Single grain weight (mg)					Grain growth rate (mg $grain^{-1}$ d^{-1})			
	10 DAH	17 DAH	24 DAH	31 DAH	38 DAH	10-17 DAH	18-24 DAH	25-31 DAH	32-38 DAH
IRATOM24	4.150 d	9.800 d	17.14 b	20.89 de	22.51 d	0.8000 a	1.040 b	0.5300 d	0.2300 cd
BINA dhan5	6.390 b	11.50 b	18.36 b	23.41 bc	24.79 bc	0.7200 b	0.9700 b	0.7200 b	0.2000 d
BINA dhan6	6.950 b	12.10 ab	20.55 a	24.39 ab	25.88 ab	0.7300 b	1.200 a	0.5400 d	0.2100 d
BRRI dhan28	5.160 c	10.79 c	17.79 b	22.25 cd	24.15 c	0.8000 a	0.9900 b	0.6300 c	0.2700 bc
BRRI dhan29	7.890 a	12.29 a	20.66 a	25.22 a	27.26 a	0.6200 c	1.190 a	0.6400 c	0.2900 b
BRRI dhan36	4.430 d	7.920 f	12.75 d	18.55 f	21.18 d	0.5000 d	0.6900 d	0.8200 a	0.3700 a
BADCI	3.750 d	9.007 e	14.70 c	20.47 e	21.69 d	0.7533 ab	0.8100 c	0.8200 a	0.1700 d
Level of significance	**	**	**	**	**	**	**	**	**
$S_{\bar{x}}$	0.233	0.209	0.457	0.532	0.532	0.018	0.031	0.018	0.018
CV (%)	7.33	3.47	4.55	4.16	3.85	4.94	5.92	4.47	10.01

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.
** = Significant at 1% level of probability
NS = Not significant
DAH = Days after heading

Appendix XVI. Data on grain and straw yield of seven modern rice varieties in *boro* season

Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
IRATOM24	5.690 c	7.330 b
BINA dhan5	6.720 ab	7.100 b
BINA dhan6	6.890 a	7.330 b
BRRI dhan28	5.820 bc	7.020 b
BRRI dhan29	7.490 a	8.917 a
BRRI dhan36	5.130 c	7.330 b
BADCI	5.450 c	6.900 b
Level of significance	**	**
$S_{\bar{x}}$	0.310	0.234
CV (%)	8.73	5.48

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XVII. Analysis of variance (mean square) of the data for different phenological stages of seven modern rice varieties in *boro* season

Sources of variation	df	Duration of different phenological stages (DAS)					
		Seedling stage	Vegetative stage	Early reproductive	Reproductive	Post-reproductive	Total life duration
Replication	2	0.669	0.978	0.745	0.876	1.529	12.81
Variety	6	5.946**	10.187**	21.196**	19.865**	9.351**	249.41**
Error	12	1.210	0.812	0.862	0.845	1.305	12.87

** = Significant at 1% level of probability

Appendix XVIII. Summary of analysis of variance for adult yellow rice stem borer (*Scirpophaga incertulas*) arrival time in boro season

Source of variation	Degrees of freedom	Mean square				1st week of March
		Adult YSB week of month of February				
		1st	2nd	3rd	4th	
Replication	2		0.004	0.006	0.953	0.001
Variety	6		0.501**	0.457**	42.218**	0.229**
Error	12		0.005	0.008	0.767	0.001

** = Significant at 1% level of probability

Appendix XIX. Analysis of variance (mean square) of the data for average plant character values and yellow rice stem borer (YSB) infestation of seven selected rice varieties of different age and session resistant and susceptible to yellow rice stem borer in boro season

Sources of variation	Degrees of freedom	No. of leaf	Length of flag leaf (cm)	Width of flag leaf (mm)	Length of 2nd leaf (cm)	Width of 2nd leaf (cm)	No. of leaf hair (sq. cm)	Life duration (days)	% YSB infestation
Replication	2	0.001	2.829	0.229	3.297	0.108	22.13	80.14	0.213
Variety	6	0.151**	61.048**	14.526**	50.341**	4.911**	11013.88**	312.12**	13.597**
Error	12	0.024	1.841	0.344	5.276	0.288	22.19	62.07	0.258
CV (%)	-	3.88	5.14	5.01	6.08	5.63	6.41	5.56	9.16

** = Significant at 1% level of probability

Appendix XX. Analysis of variance (mean square) of the data for length and width of egg masses, oviposition preference, preferencial side for oviposition and location of egg masses of *Scirpophaga incertulas* on rice leaf (EBBL, boro season)

Sources of variation	Degrees of freedom	Number of egg mass		Length of egg masses	Width of egg masses	Preferential side			Location	
		2012	2013			Dorsal	Ventral	Basal	Middle	Apical
				2013						
Replication	2	0.011	0.005	0.012	0.006	0.006	0.002	0.002	0.003	0.002
Variety	6	1.492**	0.533**	1.881**	0.646**	0.073**	0.032**	0.086**	0.111**	0.135**
Error	12	0.006	0.003	0.018	0.017	0.004	0.001	0.003	0.002	0.001
CV (%)		6.16	3.96	3.21	4.39	16.31	35.30	25.01	13.03	22.88

** = Significant at 1% level of probability

Appendix XXI. Analysis of variance (mean square) of the data for Mean yellow rice stem borer (*Scirpotationphaga incertulas*) Antibiosis indices on boro rice varieties (EBBL, 2013)

Sources of variation	Degrees of freedom	Larval				Pupal			YSB infestation (%)
		Length (cm)	Width (mm)	Weight (mg)	Survival (%)	Length (cm)	Width (mm)	Weight (mg)	
Replication	2	0.368	0.013	1.597	5.286	0.178	0.019	0.676	1.494
Variety	6	5.888**	0.376**	39.070**	330.556**	9.166**	0.258**	15.782**	194.303**
Error	12	0.659	0.026	0.714	4.619	0.207	0.022	0.576	2.688
CV (%)	-	6.66	10.43	4.62	3.65	3.79	5.76	3.24	3.98

** = Significant at 1% level of probability

Appendix XXII. Composition of *Scirpophaga incertulus* in monthly moth populations caught in light trap 2011-2012 (July to June)

	Months												
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Annual Composition**
% Infestation	71.12	89.33	85.19	92.87	87.60	14.50	5.33	28.61	57.87	96.17	97.63	98.33	83.19

Appendix XXIII. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in IRATOM24 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.438	0.012	0.003	0.005	0.002
Growth stages	2	78.726**	0.367**	0.163**	0.735**	0.196**
Error	4	0.313	0.015	0.008	0.003	0.002
CV (%)	-	3.31	5.85	10.95	5.18	15.75

** = Significant at 1% level of probability

Appendix XXIV. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BINA dhan5 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.621	0.010	0.003	0.003	0.001
Growth stages	2	83.373**	1.067**	0.288**	1.102**	0.153**
Error	4	0.428	0.005	0.004	0.005	0.001
CV (%)	-	3.84	3.26	7.46	6.59	13.32

** = Significant at 1% level of probability

Appendix XXV. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BINA dhan6 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	1.082	0.043	0.015	0.003	0.003
Growth stages	2	94.484**	0.582**	0.420**	0.737**	0.194**
Error	4	0.550	0.028	0.020	0.005	0.003
CV (%)	-	3.87	6.90	17.34	6.58	20.87

** = Significant at 1% level of probability

Appendix XXVI. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan28 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.202	0.010	0.002	0.008	0.003
Growth stages	2	70.596**	0.941**	0.305**	0.686**	0.190**
Error	4	0.459	0.005	0.004	0.010	0.003
CV (%)	-	3.82	3.41	7.73	8.54	18.13

** = Significant at 1% level of probability

Appendix XXVII. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan29 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.682	0.008	0.007	0.004	0.003
Growth stages	2	64.920**	1.052**	0.383**	0.871**	0.194**
Error	4	0.467	0.009	0.003	0.009	0.002
CV (%)	-	3.51	3.64	6.28	7.42	16.30

** = Significant at 1% level of probability

Appendix XXVIII. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages in BRRI dhan36 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.577	0.004	0.001	0.004	0.003
Growth stages	2	92.463**	0.714**	0.157**	0.962**	0.128**
Error	4	0.311	0.007	0.002	0.005	0.003
CV (%)	-	3.30	4.18	6.17	7.61	24.40

** = Significant at 1% level of probability

Appendix XXIX. Analysis of variance (mean square) of the data for assessment of crop injury caused by yellow rice stem borer (*Scirpophaga incertulas*) at different phonological stages in BADC1 during 2012-2013 (boro season)

Sources of variation	Degrees of freedom	Stem dissection				Direct field counts
		Infested hills	Infested tillers	ITWAS	DH and WH formation	DH and WH formation
Replication	2	0.370	0.015	0.002	0.005	0.002
Growth stages	2	73.162**	0.388**	0.132**	0.542**	0.132**
Error	4	0.320	0.009	0.003	0.008	0.003
CV (%)	-	3.78	4.93	6.77	9.20	21.27

** = Significant at 1% level of probability

Appendix XXX. Analysis of variance (mean square) of the data for Relative percentages of 'Dead heart' (DH) and 'White head '(WH) formation in seven different varieties during different phenological stages as computed from weekly stem dissections 2012-2013, boro Season (November - May)

Sources of variation	Degrees of freedom	**DH and WH %**		
		Active tillering	Pre-flowering	Flowering
Replication	2	0.004	0.014	0.002
Variety	6	0.490**	0.932**	0.855**
Error	12	0.004	0.015	0.003
CV (%)	-	6.93	6.87	6.17

** = Significant at 1% level of probability

Appendix XXXI Summary of analysis of variance for number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for mid-January transplanting time in boro season

Source of variation	Degrees of freedom	Mean square				
		Number of egg mass at different phenological stages				
		Seedling	Active tillering	Early reproductive	Reproductive	Post-reproductive
Replication	2	0.001	0.012	0.001	-	-
Variety	6	0.022**	0.192**	0.048**	-	-
Error	12	0.001	0.028	0.008	-	-

** = Significant at 1% level of probability

Appendix XXXII. Summary of analysis of variance for number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for early-January transplanting time in boro season

Source of variation	Degrees of freedom	Mean square				
		Number of egg mass at different phenological stages				
		Seedling	Active tillering	Early reproductive	Reproductive	Post-reproductive
Replication	2	0.001	0.001	0.007	-	-
Variety	6	0.025**	0.034**	0.026**	-	-
Error	12	0.002	0.004	0.003	-	-

** = Significant at 1% level of probability

Appendix. XXXIII. Summary of analysis of variance for number of egg masses of yellow rice stem borer (*Scirpophaga incertulas*) at different phenological stages of seven rice varieties for late-January transplanting time in boro season

Source of variation	Degrees of freedom	Mean square				
		Number of egg mass at different phenological stages				
		Seedling	Active tillering	Early reproductive	Reproductive	Post-reproductive
Replication	2	0.002	0.001	0.006	-	-
Variety	6	0.023**	0.045**	0.032**	-	-
Error	12	0.002	0.011	0.006	-	-

** = Significant at 1% level of probability

Appendix XXXIV. Percentage of infestation at different transplanting dates of seven rice varieties in boro season

Sources of variation	Degrees of freedom	EJ	MJ	LJ
Replication	2	0.555	6.647	0.090
Variety	6	14.466**	194.354**	17.633**
Error	12	0.276	2.489	0.586

** = Significant at 1% level of probability

Appendix XXXV. Yield at different transplanting dates of seven rice varieties in boro season.

Variety	EJ	MJ	LJ
IRATOM24	5.690 c	4.550 c	5.123 cd
BINA dhan5	6.720 ab	5.377 b	6.050 b
BINA dhan6	6.890 a	5.510 b	6.200 b
BRRI dhan28	5.820 bc	4.657 c	5.240 c
BRRI dhan29	7.490 a	5.990 a	6.740 a
BRRI dhan36	5.130 c	4.103 d	4.617 d
BADCI	5.450 c	4.360 cd	4.907 cd
Level of significance	**	**	**
$S_{\bar{x}}$	0.310	0.132	0.159
CV (%)	8.73	4.65	4.95

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XXXVI. Analysis of variance (mean square) of the data for yield at different transplanting dates of seven modern rice varieties in *boro* season.

Sources of variation	Degrees of freedom	EJ	MJ	LJ
Replication	2	0.303	0.002	0.174
Variety	6	2.25**	1.443**	1.826**
Error	12	0.290	0.053	0.076

** = Significant at 1% level of probability

Appendix XXXVII. Percentages of infestation of *Scirpophaga incertulas* and stubble ploughing and non-ploughing the paddy fields after immediate harvesting of seven rice varieties in boro season.

Variety	Not stubble plowing/Late sowing	Stubble plowing/Early sowing
IRATOM24	16.26 f	16.26 d
BINA dhan5	26.50 c	20.45 c
BINA dhan6	40.22 a	35.36 a
BRRI dhan28	30.00 b	24.36 b
BRRI dhan29	25.38 cd	21.55 c
BRRI dhan36	22.86 e	15.78 d
BADCI	24.66 d	24.66 b
Level of significance	**	**
$LSD_{0.05}$	1.43	2.28
$S_{\bar{x}}$	0.466	0.743
CV (%)	3.04	5.69

** = Significant at 1% level of probability
In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XXXVIII. Analysis of variance (mean square) of the data for Yield at ploughing and non-ploughing the paddy fields after immediate harvesting of seven rice varieties in boo season (2014)

Sources of variation	Degrees of freedom	Not stubble ploughing	Stubble ploughing
Replication	2	0.593	0.655
Variety	6	161.607**	131.292**
Error	12	0.653	1.659

** = Significant at 1% level of probability

Appendix XXXIX. Yield at ploughing and non-ploughing the paddy fields after immediate harvesting of seven rice varieties in boo season.

Variety	Ploughing	Not ploughing
IRATOM24	5.350 bc	5.350 c
BINA dhan5	6.320 ab	5.817 b
BINA dhan6	6.480 a	5.983 b
BRRI dhan28	5.470 bc	4.920 d
BRRI dhan29	7.040 a	6.340 a
BRRI dhan36	4.820 c	4.340 e
BADCI	5.120 c	5.120 cd
Level of significance	**	**
$LSD_{0.05}$	0.953	0.355
$S_{\bar{x}}$	0.309	0.116
CV (%)	9.24	3.72

** = Significant at 1% level of probability
In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XL. Analysis of variance (mean square) of the data for yield at ploughing and non-ploughing the paddy fields after immediate harvesting of seven rice varieties in boro season

Sources of variation	Degrees of freedom	Flooding	Not flooding
Replication	2	0.269	0.009
Variety	6	2.002**	1.416**
Error	12	0.287	0.040

** = Significant at 1% level of probability

Appendix XLI. Percentage of infestation of *Scirpophaga incertulas* with flooding and non-flooding the paddy fields after immediate harvesting of seven rice varieties in boro season.

Variety	Not flooding	Flooding
IRATOM24	6.36 d	3.48 f
BINA dhan5	7.89 d	7.89 e
BINA dhan6	25.36 a	20.15 b
BRRI dhan28	13.50 c	13.50 d
BRRI dhan29	24.33 a	22.15 a
BRRI dhan36	21.15 b	17.95 c
BADCI	20.14 b	18.85 bc
Level of significance	**	**
$LSD_{0.05}$	1.78	1.99
$S_{\bar{x}}$	0.582	0.648
CV (%)	5.95	7.57

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XLII. Analysis of variance (mean square) of the data Percentage of infestation of *Scirpophaga incertulas* with flooding and non-flooding the paddy fields after immediate harvesting of seven rice varieties in boro season .

Sources of variation	Degrees of freedom	Not flooding	Flooding
Replication	2	1.156	1.760
Variety	6	179.571**	143.265**
Error	12	1.019	1.263

** = Significant at 1% level of probability

Appendix XLIII. Yield at flooding and non-flooding the paddy fields after immediate harvesting in boro season

Variety	Not flooding	Flooding
IRATOM24	4.97 b	4.97 abc
BINA dhan5	5.87 a	5.87 a
BINA dhan6	6.02 a	5.42 ab
BRRI dhan28	5.09 b	4.58 bc
BRRI dhan29	6.55 a	5.89 a
BRRI dhan36	4.48 b	4.04 c
BADCI	4.76 b	4.29 c
Level of significance	**	**
$LSD_{0.05}$	0.700	1.03
$S_{\bar{x}}$	0.227	0.334
CV (%)	7.30	11.55

** = Significant at 1% level of probability

In a column, figures bearing same letter (s) do not differ significantly whereas means having dissimilar letters differ significantly according to DMRT.

Appendix XLIV. Analysis of variance (mean square) of the data for yield at flooding and non-flooding the paddy fields after immediate harvesting in boro season

Sources of variation	Degrees of freedom	Not flooding	Flooding
Replication	2	0.179	0.430
Variety	6	1.732**	1.664**
Error	12	0.155	0.335

** = Significant at 1% level of probability