SEASONAL ABUNDANCE, VARIETAL RESISTANCE AND INTEGRATED MANAGEMENT OF SUGARCANE STEM BORER, *CHILO TUMIDICOSTALIS* HAMPSON

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DOCTOR OF PHILOSOPHY
IN
ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

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REGISTRATION NO. 26190/00484

A DISSERTATION FOR

THE DEGREE OF
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IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY
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A DISSERTATION

**SUBMITTED
TO**

**Sher-E-Bangla Agricultural University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY (Ph.D.)

**DEPARTMENT OF ENTOMOLOGY
SEMESTER: JUNUARY-JUNE, 2017**

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SEASONAL ABUNDANCE, VARIETAL RESISTANCE AND INTEGRATED MANAGEMENT OF SUGARCANE STEM BORER, *CHILO TUMIDICOSTALIS* HAMPSON

ABSTRACT

By

Md.Yousuf Ali

Sugarcane stem borer (*Chilo tumidicostalis* Hampson) is one of the major insect pests of sugarcane in the world which causes severe infestation and significant yield loss. Five experiments were conducted in the field and laboratory to study the seasonal abundance, varietal resistance and integrated management of sugarcane stem borer, *C. tumidicostalis*. Farmer's opinion on pest status and infestation intensity of stem borer were collected from 15 upazilas under 9 major sugarcane growing districts which covered 8 sugar mill zones under 6 agro ecological zones of Bangladesh. *C. tumidicostalis* infestation data was collected directly from farmer's field in 2014 and from experimental field in 2014, 2015 and 2016. The effect of planting dates on *C. tumidicostalis* was studied by transplanting sugarcane at six different dates starting from September 2014 to February 2015 at 30 days interval. Ten sugarcane varieties were cultivated and screened to study the effect of varieties on stem borer infestation and to find out the level of resistant. Five chemical insecticides of different groups were tested in sugarcane field at BSRI farm to find out the effective one(s) against stem borer. Finally some Integrated Pest Management (IPM) packages consisting resistant varieties, suitable planting date(s), de-trashing, hand cutting and destruction of larvae use of chemical insecticides were evaluated against the stem borer to find out the best integrated management package(s). Field experiments were carried out in Randomized Complete Block (RCBD) designs at different locations. Sugarcane grower's reported several problems of sugarcane such as long duration of crop, low price of cane, insect pests, disease, low yield, delay payment of cane price and high labor cost. Of these, insect pest was the major problem for sugarcane cultivation and stem borer was the important one in all sugarcane growing regions of Bangladesh. Stem borer infestation varied from 12.44-17.20% in farmer's field. The lowest percent of stem infestation (12.44%) was recorded from Natore Sadar as against the highest (17.20%) from Ishurdi. In experimental plot at BSRI, stem infestation by *C. tumidicostalis* varied from 20.88% to 24.71% during 2014, 2015, 2016. Sugarcane grower's reported three methods such as cultural, mechanical and use of chemical insecticides for the management of sugarcane stem borer but majority of farmers (48.08%) applied chemical insecticides. They reported the use of carbofuran, virtaco and lorsban insecticides for the stem borer management but most of them used carbofuran. *C. tumidicostalis* started infestation from May and increased gradually with the age of the crops up to September then declined and sharply decreased after October and no new infestation occurred in November. The peak infestation of *C. tumidicostalis* was observed in September every year. Environmental temperature and rainfall had significant effect on sugarcane stem borer infestation. Positive relationship was observed between *C. tumidicostalis* infestation and temperature or rainfall. Planting on 15th November was the best and resulted the lowest stem borer infestation and the highest yield of sugarcane was ensured. Variety Isd 36 showed tolerance against *C. tumidicostalis* having the lowest percent of stem infestation (5.79%) and highest quantity of healthy cane yield (79.34 t ha^{-1}) compared to others. Negative relationship was observed between *C. tumidicostalis* infestation and biophysical characteristics of varieties like. Biochemical compounds, brix percentage, pol percent cane, percent reducing sugar and nutrient elements (nitrogen, phosphorous, potassium) and silicon content exert resistance effect. These compounds and elements had negative impact on stem borer infestation. Strong negative relationship was existed between stem borer infestation and presence of higher level of phosphorous, potassium and silicon content of sugarcane varieties. Nokotap (cartap) 6G @ 50 kg ha^{-1} provided maximum reduction (79.53%) of cane infestation and produced higher yield of healthy (84.62 t/ha) and total cane (87.81 t/ha). Integrated Pest Management (IPM) packages significantly reduced *C. tumidicostalis* infestation on sugarcane and increased cane yield. IPM package 7 consisted Isd 36 variety + planting on 15 November + hand cutting and removal of infested cane + de-trashing + application of Nokotap 6G @ 50 kg ha^{-1} provided only 1.54% stem infestation as against the highest (12.31%) in IPM package 9 (Isd 40 variety + planting on 15 November). IPM package 7 also provided maximum reduction (87.45%) of infestation over control and produced highest sugarcane yield (74.03 t ha^{-1}). The same package gave the highest net return (Tk. 195787.50 ha^{-1}) and maximum Benefit Cost Ratio (10.44) was obtained from IPM package 1 (Isd 36 variety + planting on 15 November + hand cutting and removal of infested cane) followed by 5.47 and 4.10 in IPM package 5 (Isd 36 variety + planting on 15 November + hand cutting and removal of infested cane + application of Nokotap 6G@50 kg ha^{-1}) and package 4 (Isd 36 + planting on 15 November + hand cutting + De-trashing), respectively.

ACKNOWLEDGEMENT

All praises are due to Almighty Allah for best owing mercy upon him and for imbibing confidence on him to materialize the research work.

Author is proud to express his deepest gratitude, deep sense of respect and immense indebtedness to his Chairman of the Advisory committee, Professor Dr. Md. Abdul Latif, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant supervision, valuable suggestion, scholastic guidance, continuous inspiration, constructive comments, extending generous help and encouragement during his research work and guidance in preparation of manuscript of the dissertation.

He expressed his sincere appreciation, profound sense, respect and immense indebtedness to the members of Advisory committee, Professor Dr. Mohammed Ali, Professor Dr. Md. Razzab Ali, Department of Entomology and Professor Dr. M. Salahuddin M. Chowdhury, Department of Plant Pathology, Sher-e-Bangla Agricultural University, for their constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the dissertation.

He would like to express his deepest respect and boundless gratitude to honorable Chairman, Associate Professor Dr. Nur Mohal Akher Banu and all the respected teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 for the valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and research work.

It is a pleasure to express his deepest sense of gratitude to AKM Delwar Hossain, the Honorable Chairman of Bangladesh Sugar and Food Industries Corporation (BSFIC), Dilkusha, Dhaka for his heartfelt co-operation throughout the study.

He expresses his deep sense of respect, gratitude to KBD Md. Mosharref Hussain, the Honorable Director (Cane Development and Research) of Bangladesh Sugar and Food Industries Corporation (BSFIC), Dilkusha, Dhaka for his valuable suggestions and encouragement during the study period.

He extends his thanks and sincere appreciation and gratitude to Md. Shamsur Rahman, Chief (Technical Services) of Bangladesh Sugar and Food Industries Corporation (BSFIC), Dilkusha, Dhaka for his kind help, encouragement and co-operation for conducting the research work.

He wishes to express his cordial thanks to BSRI especially Nuray Alam Siddiquee, SSO and scientists of entomology and field staffs for their active help during the experimental period. He felt much pleasure to convey his profound thanks to his friends for their heartiest assistance in his research and tireless effort in completing this dissertation writing. He would like to expresses cordial thanks to all other friends for their support and encouragement to complete this study.

Cordial thanks are extended to Md. Ahasanul Haque Swapan, Professor, Department of Entomology, BSMRAU for notable support, inspirations and suggestions and encouragement during study period.

He expressed his unfathomable tributes, sincere gratitude and heartfelt indebtedness from the core of his heart to his parents Md. Ayes Uddin and Kamrun Nahar, parents-in-law Md. Mohibur Rahman and Firoza Rahman, brother Dr. Mohd. Sarwar Kamal and sisters Most. Sarwar Jahan, Most. Rokeya Khatun, Most. Aktari Jahan, whose blessing, inspiration, sacrifice, and moral support and paved the way for his higher study.

In the last but not the least, expresses his deep sense of feelings and heartiest thanks to his wife, Mst. Rifat Sultana Rima, Son Enan Rahi for their sacrifices, encouragement and moral support throughout the course of the study and research.

June, 2017

The Author

CONTENTS

LIST OF TABLES

Continued

LIST OF FIGURES

LIST OF PLATES

APPENDICES

Chapter I

INTRODUCTION

CHAPTER I

INTRODUCTION

Sugarcane (*Saccharum officinarum L.*) is a perennial grass which is one of the principal cash crop used as raw material for sugar industry in Bangladesh and is cultivated in more than 100 countries of the tropical and sub-tropical regions of the world (Humbert, 1968). It is used to manufacture several types of sweetener such as white, refined, brown and raw sugar (Nayaka *et al*. 2009). In addition to sugar production, sugarcane produces many valuable by-products like alcohol used by pharmaceutical industries; begasse use for paper production, ethanol used as a fuel, and chip board manufacturing and also for the burning of sugar mills furnaces and press mud is used for organic matter and nutrients for crop production. By products also used as livestock feed. It is a sure crop and farmers are assured to some extent for returns even in adverse agroclimatic conditions.

According to FAO recommendation the minimum per capita consumption of white sugar is 13.0 kg or its equivalent quantity of 17.0 kg brown sugar per year. Total demand of sugar and gur in Bangladesh is 2.08 million tons but country produced only 0.39 million tons which was only 18.93% of total demand in Bangladesh (BSFIC 2017, DAE 2017). In global perspective to sugarcane production and yield t ha^{-1} in Bangladesh ranked 33th and 74^{th}, respectively during 2013 (FAO, 2015). There are 15 government sugar mills in Bangladesh. Daily requirement is 21000 metric tons of sugarcane for sugar production in these mills and total requirement is 40-45 lakh metric tons per season. To meet this demand of sugar it is necessary to increase the production. Sugarcane is cultivated area about 0.118 million hectare of land which is almost 44% area of the sugar mill zones, and the remaining 56% is grown in the non-mill zones in Bangladesh, where sugarcane is mostly grown for jaggary and juice production. The total area under sugarcane cultivation in Bangladesh is 0.118 million hectare with 5.27 million tonnes of sugarcane production in 2015-16. Presently 15 sugar mills are in operation under Bangladesh Sugar and Food Industries Corporation (BSFIC) with a capacity of 0.21 million tons of sugar production annually. Sugar is produced from two major crops such as sugarcane and sugar beet. Around 70% of the world's sugar is produced from sugarcane (Chowdhury and Vasil, 1993). Sugarcane is grown mainly in high and medium high land under rainfed condition. High and medium high lands are being occupied by short duration vegetable and cereal crops, to meet the high demand of foods. Sugarcane is gradually being pushed to marginal and low lying 'char' lands in Bangladesh often prone to unpredictable seasonal inundation and flash flood (Miah *et al.*, 1993). There is a little scope of expanding sugarcane area due to extensive use of land for production of additional food grain, high value vegetables and fruits.

In Bangladesh yield of sugarcane is low compare to other sugarcane growing countries due to infavourable weather, poor land condition, variable planting time, low yielding varieties, insufficient management practices, lack of knowledge of cane cultivation, poverty of farmers, small land owners, incidence of diseases and insect pests. High price of imputs and lack of scientific knowledge are the major problems in sugarcane production (Kamruzzaman and Hasanuzzaman, 2007).

Insect pests infestation is one of the major causes for low production of sugarcane; 68 species of insect pests and 02 species of mites have been identified in Bangladesh (Anon. 1973-78, 1992), which are categorized into four groups such as leaf feeders, borers, sap suckers and underground feeders. Among them 12 species of insect pests (early shoot borer, top shoot borer, stem borer, pink borer, mealy bug, sugarcane aphid, scale insect, pyrilla leaf hopper, root borer, white grub, termite and grass hopper are destructive. Insect pest infestation decreases 20% sugarcane yield and 15% sugar recovery (BSRI, 2012, Avasthy, 1983). The major insect pest of sugarcane are root borer, early shoot borer, pyrilla, gurudaspur borer, top shoot borer, sugarcane white fly and black bug etc (Bergvinson, 2004). Tweenty of sixty percent yield losses under field condition was reported by Alam (1967). Sugarcane is the habitat of more than 1500 species of insect pests throughout the world. Long and Hensley (1972) recognized 50 species of lepidopterous borers recognized as pest of sugarcane in the world. Rehman, 1942 reported 48 species insect pests from Indo-Pak subcontinent which feed on sugar crop. Sugarcane borers are the most injurious among the pests attacking this crop (Ashraf and Fatima, 1980). These includes top shoot borer, *Scirpophaga nivella* F. (Lepidoptera: Pyralidae); stem borer, *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae); root borer, *Emmalocera depressella* (Swinhoe) (Lepidoptera: Pyralidae) and Gurdaspur borer, *Acigona steniella* (Hampson) (Lepidoptera: Crambidae). Borers may reduce the yield up to 80% (Kalra and Sidhu, 1955). The damage caused by borers not only reduces the crop yield but also affects the sucrose contents of cane. Incidence of stem borer starts from the end to April and continues up to November. However, it was most abundant in June to September. There are two types of stem borer, *C. tumidicostalis* and *Chilo auricilious* are very common and destructive one in Bangladesh. *C. tumidicostalis* is the internal feeder and feed internal tissues voraciously which causes death of the plant. The newly hatched larva moves slowly towards the base of the lamina and enter into 2-4 top most internodes by boring many entry holes. The infestation due to *C. tumidicostalis* in the cane is of two types such as primary and secondary. The grown-up caterpillars migrate to the adjoining canes or to the lower healthy portion of the canes showing primary infestation (each caterpillar entering a separate cane), top leaves completely dry up and infested plant is visible from a distance. Majority of the primary infested canes showed continuity of larval tunneling and feeding in the cane starting from the tip of the spindle but some primarily infested canes showed break in the continuity of larval tunneling and feeding in the internodes which was due to feeding of the migratory fourth instar larvae and give rise to the "secondary attack". Cane tops do not dry up in this case though individual caterpillars may sometimes bore up to 5 internodes in a single attacked cane. Copious red or off white color frasses ooze out from the bored holes. Aerial root come out profusely from the nodes adjacent to the damaged internodes.

At late infestation stage, the grown up larva comes out and migrate to the neighboring canes to cause secondary infestation. The secondary infested canes show the entry holes with oozing out excreta and saw dust like damaged tissue resulting heavy losses in yield every year due to stem borer infestation. Stem borer (*Chilo tumidicostalis* Hampson) is a serious insect pest of sugarcane in Bangladesh (Karim and Islam, 1977), India (Khanna *et al*., 1957), Thailand (Suasaard *et al*., 2000) and Australia (Sallam, 2006). Pandey *et al.* (2005) reported that *C. tumidicostalis* Hampson is a major constraints of sugarcane production in different parts of the world. Incidence of *C. tumidicostalis* infestation starts from the end of April and continues upto November, which have most abundant in June to September. During 1973-1974 cropping season in Bangladesh, 100% infestation was recorded in Setabgonj sugar mill areas (Karim and Islam, 1977). In India, it caused 8.2-12.6% yield loss sometimes reaching up to 70% with 10.75-48.55% loss of sugar recovery in endemic areas (Khanna *et al*., 1957; Butani, 1961). Gupta and Avasthey (1960) also reported 25-70% and 12-60% in cane yield losses due to primary and secondary infestation, respectively in different sugarcane varieties, along with 0.5-3.5 unit loss of sugar recovery in West Bengal, India. Hall (1986) reported more than 45 percent of yield losses in sugarcane are due to infestation by borer pests alone.

Establishing an insect management program for sugarcane insects is important to avoid economic losses.

Different pest management practices are available to control *C. tumidicostalis.* To control stem borer pests and others alike a multitactic system of pest control needs to be implemented which should include predators, resistant genotypes, culture practices and finally insecticides. Different management practices have been applied to borer control in various regions of sugarcane world such as Cultural control (resistance genotypes or varieties cultivation, different planting/sowing time, de-trashing, tying or wrapping), mechanical control (hand cutting infested plants and remove from field), biological control, chemical treatment and finally integrated pest management practices. Integrated pest management (IPM) approach involving non-chemical alternatives, resistance varieties have been undertaken in the USA, Canada and Australia (Forrester, 1990). Cultural control like burnig, clean cultivativation, early sowing and ploughing fields after harvest have been recommended (Butani and Jotwani, 1984; Chauhan, 1989 and Yawalkar, 1985). Varietal screening may be one of the most valuable methods to find out tolerant/resistant varieties and include it in integrated pest management (IPM) strategy. Host plant resistance is an important component of any strategy aimed at reducing the economic impact of crop pests. David and Sitananthan (1986) suggested that IPM may be practiced to maximize safety of natural enemies like parasitoids, predators, pathogens and varieties.

It is based on three factors: antibiosis, antixenosis, and tolerance. Antibiosis is based on the plant inhibiting the development of the feeding insect, while antixenosis acts by influencing adult and/larval behavior on the surface of the host plant. Most studies have focused on antibiosis, although pubescence in sugarcane can be important. Selecting planting date was studied/experimented to reduce damage to the crop caused by *S. cretica* in the Sudan (Amin., 1988).

The chemical control method is still popular to the Bangladeshi farmers because of its quick and visible results (Anon., 1994). The frequent and indiscriminate use of insecticides and overwhelming reliance on it results various complications such as development of resistance to most commonly used insecticides, trade implication, poisoning, hazards to non-target organisms, increased production cost etc. They may cause resurgence and upset of new insect pests and health hazards to wild life, resulting in disruption of natural control system in other crop field and pests (Rajendran, 2006; Pedigo, 2002). Different management practices have been developed and adopted in mill and non-mill zones of sugarcane to maintain the pest population below ETL. Alam and Biswas (2003) tried to develop an Integrated Pest Management (IPM) package using two or three methods as its components against sugarcane stem borer in Bangladesh. The comparative efficacy of different management tactics including some non-chemical and selected insecticides for development of suitable integrated pest management approach using safer components are not properly addressed in Bangladesh. Under the above circumstances the present study was undertaken to evaluate the effectiveness of cultural, mechanical and chemical IPM components to control stem borer of sugarcane and to compare the economics of the management practices singly or in combinations.

Therefore the present study was undertaken to fulfill the following objectives:

Objectives:

1. To study the pest status of sugarcane stem borer in Bangladesh and its population dynamics in relation to climatic factors;
2. To find out the optimum planting time that ensure low infestation of sugarcane stem borer;
3. To screen out resistance varieties and to identify the resistant sources against sugarcane stem borer;
4. To find out the effective chemical insecticides for the management of sugarcane stem borer and
5. To develop integrated management package(es) against sugarcane stem borer infesting sugarcane.

Chapter II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Sugarcane stem borer, *Chilo tumidicostalis* Hampson is one of the most destructive insect pests of sugarcane in the world and considered as an important obstacle for economic production of this crop. Substantial works have been done globally on stem borer about its origin, geographical distribution, taxonomy, biology, ecology, seasonal abundance, host range, nature of damage and their management. In Bangladesh, few studies were done and the information about species identification, seasonal abundance, varietal screening and management practices of stem borer are insufficient. Available and accessible sources of information on *C. tumidicostalis* have been thoroughly reviewed and summarized with critical comments as appropriately as possible. Most of the available information originated from outside Bangladesh because there have been little research on *C. tumidicostalis* in the country. In the literature review, all available relevant information in Bangladesh and elsewhere related to sugarcane stem borer attacking sugarcane were gathered and presented under the sub-headings of taxonomy and nomenclature, seasonal abundance and geographical distribution, biology, life history and life cycle, host range, nature of damage, ecology, yield loss, morphological and biochemical resistant parameters, management practices and Integrated Pest management (IPM).

2.1 Taxonomy and Nomenclature

2.1.1 Taxonomy

Kingdom: Animalia
  Phylum: Arthropoda
    Sub-phylum: Hexapoda
      Class: Insecta
        Sub-class: Pterygota
          Infraclass: Neoptera
            Division: Endopterigota
              Order: Lepidoptera
                Family: Pyralidae
                  Genus: *Chilo*
                    Species: *Chilo tumidicostalis* Hampson (Hampson, 1919)

2.1.2 Nomenclature

The sugarcane stem borer species collected from Pabna, Bangladesh was identified as *Argyria tumidicostalis*, while the same species collected from kanny Koory in Cacha (lower Assam) was named as *C. gemininotalis* (Hampson, 1919). Kapur (1950) transferred the genus *Argyria* to *Chilo* and named it as *C. tumidicostalis* Hampson. It was referred to as plassey borer by Gupta (1957) because of its occurrence in an epidemic form at plassey of west Bengal during 1956.

2.2 Geographical distribution of *C. tumidicostalis*

Lepidopterous stem borers are major pests of sugarcane in most countries of the world. Sugarcane stem borer, *C. tumidicostali* is a versatile and widely distributed polyphagous insect. According to geographical distribution, host plants and potential of invading Australia is provided for 36 stem borer species (Sallam, 2006). *C. tumidicostalis* was a pest of sugarcane in southern Asia (Neupane, 1990). It had been reported in an epidemic form at Plassey in Nadia district of West Bengal, Jorhat and Cachar districts of Assam and Dimapur district of Nagaland (Avesthy, 1982) Purnea, Bhagalpur, Monghyr and Darbhanga districts of Bihar (Khanna *et al*., 1957).

2.3 Biology of *C. tumidicostalis*

There were four stages in life cycle of *C. Tumidicostalis* which were completed in 30-85 days and 5-6 generation per year depends on availability of food and climatic condition (hot, cold and drought) in tropical and sub-tropical region. The moth emerges during at night and is attracted to light. Mating and oviposition take place only at night. Rainfall appeared to favor borer multiplication. However, under drought condition, profuse egg lying takes place in the month of June. High atmospheric humidity also favors rapid build-up of the borer population (Gupta and Avasthy, 1957). The incidence of the pest is significantly higher in heavy soils and under water logged and flooded conditions (Khanna *et al*., 1957). Infestation is highly increased in the ratoon cane than new plant cane.

C. tumidicostalis was the most serious pest of sugarcane and the adult female mainly laid egg on the leaves. The duration of egg, larva, pupa and adult stages were 9, 25-30, 7-10 and 3-5 days, respectively and the total life cycle was 46-49 days, the average number of eggs emerging in the field was 96 percent (Pitaksa, 1999).

2.3.1 Egg

The moths are nocturnal in habit. Emergence starts after dusk and continues till midnight, though the rush of emergence occurs between 8 and 11 pm. The moths show a high degree of photo-tropism and are easily attracted to light. Mating and egg laying were observed after 10 pm. When freshly laid, the egg is flattened and dirty white in color with a light greenish tinge. The number of eggs in one egg mass varies between 87 and 250, and the size of the egg mass varies between 8-10 mm in length and 2-4mm in width (Atwal and Dhaliwal, 2007). The eggs are whitish grey in color and laid in batches on outside of newly opened 2-3 top leaves. Eggs may also be laid one the leaf sheath and sometimes in stalk. Each egg mass consists of 90-250 eggs (Gupta, 1960). One female deposits about 800 eggs in 4 to 5 egg masses. The eggs are laid in typical pyralid fashion in tiers of 2 to 4 eggs on the underside of the recently opened first, second and third leaves. Often the eggs were observed on the leaf sheaths as well as the cane (Atwal and Dhaliwal, 2007).

2.3.2 Larva

Hatching occurs after about 7 days of incubation, and takes place early in the morning. The full grown caterpillars (22-32 mm × 3.5 mm) have 4 broad longitudinal stripes and many grey tubercles. Four different types of larva are found (Larval polymorphism) viz., both stripes and tubercles present in the first type, faint stripes and prominent tubercles present in the second types. Both stripes and tubercles faint in the third type, stripes absent and tubercles faint in the forth type. Larval period ranges from 27-40 days. Newly formed pupae are light brown but turn to dark brown later. The 5^{th}, 6^{th} and 7^{th} abdominal segments of the pupae are provided with prominent and strongly chitinized and branched spines. On the second day after hatching a faint, fine, short and black line appears in the middle. This grows in size and becomes darker on the 3rd day. The embryo becomes discernible on the 5th day, and the head of the caterpillar a deep black spot appear on the 6th day (Atwal and Dhaliwal, 2007).

2.3.3 Pupa

Freshly formed pupa is light brown in colour, but turns to dark brown in due course. Front extends upward into two chitinized ridge-like projections. The 5th, 6th and 7th abdominal segments are provided with prominent and strongly chitinized and branched spines. The ring is complete on the 7th segment only, and incomplete on 5th and 6th segments. Anal segment is short and the dorsal half carries two short chitinized lobes while the ventral half has two spines on each side. The pupae formed in the laboratory were smaller in size (12.3 mm length and 2.7 mm width) than those collected at Plassey (16.3 mm length and 3.5 mm width). The duration of the pupal stage was 6-11days. During, August and September, one life cycle was completed by 44-83 days at maximum temperature range of 84-94.7° F. The relative humidity during this period ranged between 65% and 85% in the morning, and 53% and 82% in the evening hours. The incubation, larval and pupal stages lasted on an average for 7, 40 and 9 days, respectively (Atwal and Dhaliwal, 2007).

2.3.4 Adult

Rahman *et al.* (2013) identified morphological characteristics of stem borer species with standard keys and species composition was only predominated by *C. tumidicostalis*, though previous workers found other borers in addition to this species. Moths are medium size, nocturnal and attracted towards lights. Front wings are dark brown with many scattered black scales. Terminal row of black spots is present in each forewing. Hind wings are whitish except for a few brown scales in the coastal area in the male moths. *C.tumidicostalis* was the most serious pest of sugarcane and the adult female mainly laid egg nearly along the leaves. The duration of egg, larva, pupa and adult stages were 9, 25-30, 7-10 and 3-5 days, respectively and the total life cycle was 46-49 days, the average number of eggs emerging in the field was 96% percent (Pitaksa, 1999).

2.4 Host range

C. tumidicostalis is an oligophagous pest attacks several host crops under poaceae family. Calatayud *et al.* (2006) noted that in sub Saharan Africa, lepidopteran stem borers cause severe damage and yield loss to graminaceous crops such as maize, sorghum and sugarcane. Ongamo *et al.* (2006) reported that the presence of wild host plants of stem borers in cereal growing areas. Fanindra et al. (1990) reported *C. tumidicostalis, C. auricilius* Dudgeon, *C. infuscatellus* Snellen, *C. partellus* (Swinhoe), *C. polychrysus* (Meyrick), *C. suppressalis (Walker), C. suppressalis (Butler), C. sacchariphagus indicus (Kapur), and C. supermain* as pests of cereal crops in southern Asia. *C. partellus* caused severe losses in maize, sorghum and rice; *C. suppressalis, C. polychrysus* and *C. supermain* were major pests of rice; *C. auricilius* caused damage on both rice and sugarcane; and *C. infuscatellus* and *C. sacchariphagus indicus* were serious pests of sugarcane. *C. suppressalis* simplex and *C. tumidicostalis* are minor pests of maize and sugarcane, respectively. Nair *et al.* (1986) obtained stem borer as pest of *Saccharum spontaneum* L and *Sclerostachya fusca* (Roxb.) in Assam.

2.5 Nature and extent of damage

2.5.1 Nature of damage

The incidence of this borer in a field can be easily spotted by the presence of dry crown of leaves on the infested canes. The injury due to borer in the cane is of two types, primary infestation and secondary infestation.

2.5.1.1Primary infestation

It is caused by the newly hatched larvae congregating in the top 3 to 5 internodes of a cane. More than 100 caterpillars may be collected from a single cane. Fresh frass which was shining red in color was usually seen coming out of the holes in the top internodes. The leaves of such canes ultimately dry up. The affected internodes break off easily. The nodes adjacent to the infested internodes throw out elongated sett-roots which envelop the stalk below. Sprouting of side-shoots also sometimes occurs (Atwal and Dhaliwal, 2007).

2.5.1.2 Secondary infestation

The grown-up caterpillars migrate to the adjoining canes or to the lower healthy portion of the canes showing primary infestation (each caterpillar entering a separate cane) and give rise to the "secondary attack". Cane tops do not dry up in this case though individual caterpillars may sometimes bore up to 5 internodes in a single-attacked cane (Atwal and Dhaliwal, 2007)

2.5.2 Extent of damage

Chohan, *et al*. (2014) reported that the insect pest infestation started in ratoon crop and was remained 20.32% higher than plant crop. Stem borer accounted high infestation followed by top shoot and root borer among the genotypes. The results were in accordance with Bhatti *et al*. (2008). Gupta *et al*. (1959) estimated that losses due to borer attack varied from 5.67 to 16.19 ton of sugarcane ha^{-1} and Ishtiaq, (2005) accounted the losses (0.25 to 1.25%) in sugar recovery.

Gupta and Sarma (2007) reported that plassey borer; *C. tumidicostalis* caused damage at different intensity and affecting various yield parameters and juice quality of sugarcane (var. Co 6315) under the agro-ecological condition of Assam. An average reduction in cane weight, juice weight and bagasse weight of damaged canes over healthy ones were recorded to a tune of 28.00%, 29.68% and 24.06%, respectively. This resulted the maximum decrease of 38.00% of cane weight, 42.59% of juice weight in canes with 7 damaged internodes and 33.33% decreased of bagasse weight in cane with 5 damaged internodes. Damage intensity with 6 damaged internodes was found to cause the maximum deterioration in juice quality followed by 8 damaged internodes. A maximum reduction of glucose and sucrose were 58.15% and 18.46%, respectively. An average reduction of 42.97% in glucose and 12.62% in sucrose was observed under different damage intensities.

Goebel and Way (2007) investigated the impact of infestation on sugarcane yield of two key stem borer species, *C. sacchariphagus* and *Eldana saccharina* over a period of 10 years in Reunion Island and South Africa. The relationship between borer injury (measured as percent bored internodes) and the corresponding stalk length and diameter, biomass, fibre and sugar content were determined. Borer injury impaired the growth and reduced quality of sugarcane stalks. *C. sacchariphagus* decreased stalk biomass to a greater extent than sucrose content. *E. saccharina* injury reduced sucrose content and increased fibre level and affected to a lesser extent stalk biomass.

Alam *et al*. (2006) reported the weight and recovery losses caused by top shoot borer, stem borer and rootstock borer at the experimental farm of Bangladesh Sugarcane Research Institute (BSRI), Ishurdi, Pabna during the cropping season 2002-2003. Results revealed that mean weight losses were 12.29% and 46.68% for top shoot borer (TSB), 1201% and 34.51% for stem borer (SB) and 10.07% and 55.28% for root stock borer (RSB) at 10% and 100% infestation level, respectively. At 100% infestation of TSB, SB and RSB caused losess of 8.44%, 10.95% and 08.48% mean percent recovery. The result proved that through recovery loss due to pest infestation was different for different varieties but losses generally increased with the increased in infestation.

Abdullah *et al*. (2006) estimated weight and recoverable sucrose loss for three sugarcane cultivars in three sugar mills located at Thakurgaon (TSM), Setabgonj (STSM) and Pancharar (PSM), Bangladesh from 28 to 30 October 2004. Stem borer infestation resulted in weight loss and reduced sucrose content of the cane. Weight and sucrose loss increased with the increase in the number of borers per infested cane. Weight losses of 28.73%, 18.64% and 18.01% and sucrose losses of 9.74%, 11.21% and 15.93% were highest Isd 16, Isd 21 and Isd 30, respectively, having more than three bores per infested cane. Abdullah *et al.* (2006) studied six promising sugarcane clones viz., 245-99, I 262-99, I 429-99, I 433-99, I 446-99 and I 486-99 and two standard varieties Isd 20 and Isd 32 against some major insect pests. Top shoot borer and stem borer infestation ranged from 4.55 to 53.58 and 5.25 to 55.21%, respectively showing the highest infestation in the clone I 429-99 compared to standard varieties.

Abdullah *et al*. (2004) reported that stem borer, *C. tumidicostalis* Hampson infesation ranged from 14.54 to 33.74% (stalk basis) with the intensity of 10.05% in the clone 1143-96 compared to standard Isd 28. Biswas *et al.* (2004) reported that *C. tumidicostalis* infesation (stalk basis) was minimum (8.48%) in 216-92 followed by 1592 (9.18%). Bhardwaj *et al.* (1980) noted that to incidence of 32.38% and intensity of 5.3-8.0 % of stalk borer resulted a loss of 4.0% and 0.5 units in cane yield and sugar recovery, respectively. Two species of stem borer, viz., *C. tumidicostalis* Hampson and *C. auricilious* Dudgeon attacking sugarcane stem. The former one was considered as a major pest and its incidence was common every year. Its appearance ranged from May to harvest of the crops and caused considerable damage (Anon. 1979).

Gasper *et al*. (1978) reported the average recoverable sugar loss in the sugar crops was 0.025 kg ton^{-1} cane for 1% for borer internodes. Schaff (1975) reported in Jamaica that borer internodes produced 45% less sugar than undamaged internodes and the borer caused variable damage to the sugarcane crop. Humbert (1976) showed in Mexico and found and average loss of 300 grams of sugar per metric ton of cane for every 1% infestation of internodes, this combined with loss of nearly 1500 tons from 900000 tons.

Kulshrestha and Avasthy (1957) reported 12% loss in yield and 1.95 units in sugar recovery at 40% incidence and 20% intensity of stalk borer. Gupta and Avasthy (1960) reported as high as 70% in cane yield and 0.5 to 3.5 unit losses in sugar recovery by *C. auricilious* Dudgeon which was a major pest which prevailed every year. Alam (1967) reported that insect pests alone caused sugarcane damage ranging from 20-60% under the field condition.

Begum *et al.* (2006) carried out an experiment on the nature of damage caused by major insect pests of sugarcane at Bangladesh Sugarcane Research Institute (BSRI) farm during the cropping season 2004-2005. This observation was beginning from the first week of March 2005 and continued up to March 2006. Weekly data collected on infestation level and natural enemies of major pests. Ten clumps per week were uprooted and dissected for RSB. Ten sweeping were done per week to observe existing pests (moth/adult/beetle) and their natural enemies. The highest stem borer infestation was 27.52% at BSRI farm, Ishurdi, Pabna and the lowest 0.56% in November. In cane of RSRS farm, Thakurgaon the lowest infestation 5.68% was found in June and the highest infestation 60.37% was observed in December. The infestation of TSB ranged from 0.38% to 48.27%. The highest (48.27%) infestation was recorded in the month of August 2005 and lowest (0.38%) in February 2006. The incidence was increased from June 2005 to October 2005 and decreased from November to February 2006. The RSB infestation starts from first or second week of March. The highest (22.82%) infestation was recorded in September.

Kolo*et al.* (2000) reported that the economic loss caused by stemborers in chewing cane was studied at the experimental field of National Cereals Research institute, Edozhigi in Niger State. Field infestation was as high in chewing canes (*Saccharum officinarum*L.) having 23.7% resulting about 30.8% loss of expected income. This huge loss in income of local farmers emphasizes the need to urgently formulate effective control measures against stem borer attack.

Agarwal (1969) reported that sugarcane is attacked by many insect species. Box (1953) listed 2041 insects including Acarina, covering 98 families under 13 orders. The sugarcane crop suffers from the attack of some insect or other all through its growth e.g., the seed (setts) and the seedlings are damaged by termites, shoot and root borers and soil grubs. Later, the leaves are infested by fulgorids, aleurodids, chinch bug, coccids, grasshoppers, army worms, and mites, etc. The stalk is damaged by about a dozen species of tissue borers, coccids and beetle borers, etc. Fortunately, all the insect pests are not serious in all the areas or seasons. They are highly specific in time, space and food preferences.

Alam *et al.* (2006) observed 100% infestation of SB caused losess of 10.95% recovery. Avasthy (1983) obtained the estimated losses of 20% in cane yield and 15% in sugar recovery caused by sugarcane stem borer. Bhardwaj *et al.* (1980) noted that to incidence of 32.38% and intensity of 5.3-8.0 % of stalk borer result a loss of 0.5 unit sugar recovery. Kulshrestha and Avasthy (1957) reported 1.95 units in sugar recovery at 40% incidence and 20% intensity of stalk borer. Gupta and Avasthy (1960) reported as 0.5 to 3.5 unit losses in sugar recovery due to stem borer which is a major pest prevailed every year in West Bengal, India. Sugar recovery losses 10.75-48.55% was reported in India due to stem borer infestation (Khanna *et al.*, 1957, Butani, 1961). Kulshrestha and Avasthy (1957) reported 1.95 units in sugar recovery at 40% incidence and 20% intensity of stalk borer.

Sucrose losses of 9.74%, 11.21% and 15.93% in varieties Isd 16, Isd 21 and Isd 30 respectively resulted due to stem borer infestation (Abdullah *et al.* 2006). Schaff (1975) reported in Jamaica that internode borers produced 45% less sugar than undamaged internodes and the borer caused variable damage to the sugarcane crop. Humbert (1976) showed average loss of 300g sugar per metric ton of cane for every 1% infestation of internodes, this combined with loss of nearly 1500 tons from 900000 tons.

2.5.2.1 Internode infestation

Rahman *et al*. (2013) conducted field surveys during the cropping season of 2010-2011 to assess the distribution of Sugarcane stem borer species in 12 AEZs of Bangladesh. These surveys documented abundance and their distribution and results clearly showed the existence of the stem borer at all locations surveyed, but with a higher incidence in the Atwary, Thakurgoan (36%) and initiation of infestation was observed on 20 May. Stem borer incidence and distribution varied significantly among different locations. Second highest rate of infestation (32%) was recorded in Bashudebpur (Natore) followed by Sultanpur farm, Dinajpur (31%), Pabna and Akandabaria farm, Carew and Co. Bd. Ltd. (30%). The lower infestation was recorded in Kaliganj. The percentage of stems attacked at the Jhenaidhah (Kaliganj) has never exceeded 23% followed by Rajshahi (28%), Thakurgaon and Faridpur (29%). The rate of infestation of stem borer (*C. tumidicostalis*) in different locations varied from 23-36%. While morphological characteristics of stem borer species were identified with standard keys and species composition was only predominated by *C. tumidicostalis*, though previous workers found other borers in addition to this species. The sex ratio of adult moth *C. tumidicostalis* was 1:1.42 after emergence from the reared pupae collected from different locations.

Ullah *et al*. (2006) reported that cane and internode damage in sugarcane cause by top shoot borer, stem borer, termite and rodent was studied at four localities (Mandi Bahauddin, Phalia, Bhalwal and Khushab) in Punjab, Pakistan, during 2003-04. The results revealed that 4000 cane samples, which had 60289 internodes, had 2759 damaged internodes (4.58%) caused by sugarcane pest complex. The overall internodes damage caused by top shoot borer, stem borer, rodent and termite reached 2.20%, 1.31%, 0.19% and 0.13%, respectively. The overall cane damage was high (20.10%) for top shoot borer category, followed by stem borer (10.00%), rodent (6.00%), top shoot borer + stem borer (3.95%), termite (1.27%), and top shoot borer + rodent (1.22%). Categorized cane damage was less than one percent for stem borer + rodent (0.75%), top shoot borer + termite (0.20%), top shoot borer + stem borer + rodent (0.20%), stem borer + termite (0.10%), rodent + termite (0.07%) and top shoot borer + stem borer 8520/ + termite (0.05%). The highest reduction (21.67%) in sugar recovery was recorded for topshoot borer + stem borer + termite followed by stem borer (bottom, 19.28%), termite (19.01%), top borer + stem borer (12.76%), stem borer (middle, 10.90%), rodent (10.77%) and top shoot borer (5.45%).

Bhuyan *et al.* (2001) carried out investigation on the nature of damage caused by plassey borer, *C. tumidicostalis* in Jorhat, Assam, India during 1999-2001. They observed significant variation on the proportion of damage length in the primary and secondary infested cane in different months. The mean proportion of damaged length caused by the larvae in primary infested cane was 0.47, 0.46 and 0.42 respectively in August, September and October as against 0.16, 0.11 and 0.12 in secondary infested cane. The proportion of damaged length was significantly high in the primary infested canes than secondary infested. However, proportion of damaged length in primary and secondary infested canes during the different months was found statistically non-significant. Majority of the primary infested canes showed continuity of larval tunneling and feeding in the cane starting from the tip of the spindle but some primarily infested canes showed break in the continuity of larval tunneling and feeding in the internodes which was due to feeding of the migratory fourth instar larvae. In the secondary infested canes, the spindle of the cane was not at all damaged and only the internodes below the base of the spindle were bored in contrast to the larval damage starting from tip of the spindle onward in the primarily infested canes.

Schaff (1975) reported in Jamaica that internode borers produced 45% less sugar than undamaged internodes and the borer caused variable damage to the sugarcane crop. Humbert (1976) in Mexico showed average loss of 300 g of sugar per metric ton of cane for every 1% infestation of internodes, this combined with loss of nearly 1500 tons from 900000 tons.

2.6 Field survey

Rahman *et al.* (2013) conducted survey during the cropping season of 2010-2011 to assess the distribution of Sugarcane stem borer species in 12 AEZs of Bangladesh. These surveys documented abundance of SB and their distribution and results clearly showed the existence of the stem borer at all locations surveyed, but with a higher incidence(36%) at Atwary, Thakurgoan and initiation of infestation was observed on 20 May. Stem borer incidence and distribution varied significantly among the different locations. Second highest rate of infestation (32%) was recorded in Bashudebpur, Natore followed by Sultanpur farm, Dinajpur (31%), Pabna and Akandabaria farm (Carew and Co. Bd. Ltd) (30%). The lower infestation was recorded at Kaliganj. The percentage of stems attacked at the Kaliganj has never exceeded 23% followed by Rajshahi (28%), Thakurgaon and Faridpur (29%). The rate of infestation of stem borer (*C. tumidicostalis*) in different locations varied from 23-36%. Khanna *et al.* (1957) conducted pest survey at

Purnea district in Bihar during 1940. Severe and characteristic damage was done to mature canes by stem borer. Detailed examination of larval and pupal characteristics establishes the identity of the pest is *C. tumidicostalis*.

2.7 Seasonal abundance of *C. tumidicostalis*

The abundance of major sugarcane insect pests like top shoot borer, stem borer and rootstock borer were investigated for the last 28 years from 1980 to 2007 at BSRI, Ishurdi, Pabna. The incidence of these major insect pests occurs in the months of March to October. The abundance of top shoot borer, *Scirpophaga excerptalis* Walker, was positively correlated with rainfall (r = 0.448) in the month of June, where temperature and humidity did not affect significantly on their incidence. Stem borer, *C. tumidicostalis* Hampson, was found positively correlated with average maximum temperature in July (r = 0.399), and negatively correlated with average minimum temperature in October (r = −0.379) where humidity and rainfall did not affect significantly on their incidence. The abundance of rootstock borer, *Emmalocera depressella* Swinhoe, was positively correlated with average maximum temperature (r = 0.525), and negatively correlated with rainfall in the month of May (r = −0.563) and September (r = −0.380). Top shoot borer and rootstock borer infestation were increased by 2.09 and 1.43%, respectively, during the last 28 years. Maximum and minimum temperature was increased by 0.18% and 0.22%, respectively, in the month of May during the last 28 years.

Gupta and Sarma (2007) noted that seasonal variations in growth, longevity and gravimetric parameter of sugarcane stem borer, *C. tumidicostalis* was studied on plant sugarcane as well as on second ratoon sugarcane grown in the rainfed agro-ecosystem of Assam, India. The larva passed through six instars on both plant and ratoon canes in both seasons. The larval period, pupal period and total (larval + pupal) duration were longer in

December- February than in July-August on both plant and ratoon canes. The growth indices in July-August were approximately twice than those in December-February for both canes. The instar-wise seasonal variations in gravimetric parameter showed different trends on plant and second ratoon canes. On plant cane, such variations were significant in 2nd, 3rd and 6thinstar and non-significant in 4th and 5th instars; whereas, on 2nd ratoon cane, the difference was highly significant in 2nd, 3rd, 4th and 5th instars and non-significant in 6th instar.

Gupta and Rabha (2003) reported that the growth and development of sugarcane plassey borer, *C. tumidicostalis* in 2001-2002 on plant and second ratoon sugarcane by rearing the insect on the excised internodes of the canes in a growth chamber at temperature of 30±1ºC, relative humidity of 80%±2 and 12.12 light and dark hours. The mean larval duration (53.3 days), pupal duration (10-12 days) and total life cycle (61-72 days) were considerably shorter and growth index (101.3%) was higher on plant canes compared to those reared on second ratoon sugarcane which were 63.5 days, 10-12 days and 70-90 days, respectively. The weight gained by the different larval instars and dry frass excreted were also significantly higher when reared on plant canes than second ratoon canes. Attractiveness of the plant cane by *C. tumidicostalis* appeared to be due to difference in the nutritional content in respect of nitrogen, phosphorous and potash which were of higher level in plant sugarcanes than ratoons and also due to early maturity and accumulation of sugar in rations over plant canes.

Six broods of the borer were observed during one crop season at Plassey. The eggs of the first brood were deposited during the last week of June and the first week of July 1956. The larvae started pupating by the end of the month, and emergence of the moths, as well as oviposition for the second brood, started in the first week of August. The eggs of the third brood were deposited in early October 1956 and the larvae went into hibernation by the middle of November. The caterpillars became active again with a rise in temperature during the middle of February 1957. The eggs of the fourth brood were deposited during the second fortnight of February and the first week of March 1957, those of the fifth brood during the second fortnight of April, and those of the sixth brood during the second fortnight of May 1957. It might be pointed out here that, from the fourth brood on, it was difficult to ascertain the beginning and the completion of the broods because moths, eggs, larvae, as well as pupae, were simultaneously available in the field in abundance (Gupta and Avasthy, 1959).

In India, Cotes (1889) was the first who attempted to give specific name to the sugarcane moth borers. He erroneously named all the borers as *Diatrcea saccharalis* Fb. But being aware of the unsatisfactory systematic position of the Indian species the same were sent to Dr. Riley, who identified these as species of *C. nearing C. plejadellus Zinck* or *C. infuscatellus Snell.* Hampson (1919) described the adult of *Argyria tumidicostalis* recorded from Bengal and *C. gemininotalis* recorded from Assam. Kapur (1950) re-examined the material from Assam and Bengal and opined that both these species were synonyms and should be renamed as *C. tumidicostalis*.

2.8 Management practices of *C. tumidicostalis*

2.8.1 Cultural Practices

2.8.1.1 Sowing times

Planting time may affect the incidence of borers in sugarcane. Autumn planting generally protects the crop against shoot borers, Gurdaspur borer, top borer, termites and white grubs in subtropical India (Virk *et al.*, 2013 and Kalra, 1963). However, autumn planted crop suffers more seriously from ravages of stalk borer than the spring planted one. This may be attributed to better growth of the crop when planted in autumn due to longer period to growth and advancement of cane formation. Autumn planting of sugarcane may be avoided in the areas where stalk borer infestation is high and to check the buildup of pest population; heavily infested crop should not be rattoned (Khan *et al.*, 2006; Virk *et al.*, 2013). The higher incidence of the top shoot borer has been reported during January to April in the November planting, February to March in December planting and during May in the January planting in case of *Eksali* crop in Andhra Pradesh. The incidence of top shoot borer decreased with the progress of plantings, being highest in November planting and lowest in February planting (Khan *et al.* 1965). In north India, planting the crop early i.e. before the mid of March has been found very effective in lowering the incidence of shoot borer (Virk *et al.*, 2013).

2.8.1.2 Detrashing

In the months of October and November, de-trashing results in reduction of damage caused by stalk borer (Virk *et al.*, 2013 and Madan, 2001). The removal of dry leaves and burning of the trash to destroy the larvae and pupae attached with the leaf sheaths proves helpful and is generally recommended for controlling the internode borer. The detrashing at fifth, seventh and ninth month's stages of the crop growth checks internode borer damage (Virk *et al*., 2013). Similarly, removal of lower leaves during 5^{th} and 9^{th} month stages of crop growth is effective in reducing the activity of internode borer, scale insects, mealy bugs, whitefly and pyrilla (Khan *et al*., 2006).

The percent infestation, yield potential, loss in weight and loss in sugar recovery the package (Comprising planting of borer free sett + removal of primary stem borer infested cane + de-trashing in June through September + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August) was judged as the most effective, profitable (Rahman *et al*., 2015). Management of sugarcane stem borer by using T*richogramm*a cards, de-trashing, light traps and chemical control; the minimum infestation (8.71%) was recorded in combination of Trichogramma cards + Detrashing + Light traps (Ahmad *et al.*, 2011). Integrated pest management (IPM) programme included trash mulching, late season planting, irrigation once a week from the third to the tenth weed, earthing-up after the second weeding and fertilizer application, de-trashing the cane during the fifth and seventh month of cultivation, release of egg parasitoid *Trichogramma chilonis* and harvesting at the 12 month without delay, increased the milleable canes and yield of the crop by 36.45% and reduced the infestation of the crop by *C. tumidicostalis* (Rajendran, 2006).

2.8.1.3 Variatal resistance

Islam *et al*. (2016) seven sugarcane varieties viz., Isd 33, Isd 34, Isd 35, Isd 36, Isd 37, Isd 38 and local variety (standard) to evaluate their response against some major insect pests at Chunarughat upazilla in Habigonj district under Akhaura Terrace soils (AEZ-30) during the cropping season of 2009-2010. Root stock borer infestation was higher which ranged from 30.45-39.55% with the lowest infestation (30.45%) was found in Isd 37. Stem borer infestation ranged from 22.82-35.99% with the lowest infestation (22.82%)

was found in Isd 37. Top shoot borer infestation ranged from 10.46-13.93% with the lowest infestation (10.46%) was found in Isd 34. Early shoot borer infestation ranged from 3.18-6.44% with the lowest infestation (3.18%) was found in Isd 38. Black beetle infestation ranged from 5.94-8.60% with the lowest infestation (5.94 %) was found in standard variety. Mealy bug infestation ranged from 9.17-12.23% with the lowest infestation (9.17 %) was found in Isd 37. Scale insect infestation ranged from 4.21-5.96% with the lowest infestation (4.21 %) was found in Isd 34. Termite infestation ranging from 30-72.66 (no. of population/5 clumps/plot) and the lowest population (30) was found in Isd 38. In case of white grub, infestation ranging from 4.40 to 5.38 (no. of population/5 clumps/plot) and the lowest population (4.4) was found in Isd 36. Isd 37 and Isd 38 were tolerant to root stock borer, stem borer, mealy bug, early shoot borer and termite. Therefore, Isd 37 and Isd 38 may be recommend for commercial cultivation in terms of tolerance against insect pests and yield.

Chohan *et al.*, (2014) reported that comparative performance of 12 sugarcane genotypes were tested in 4th stage against two local check varieties at National Sugar Crops Research Institute, Thatta. Study aimed at to identify potential sugarcane genotypes for releasing them as new commercial variety(es) in future. Significant differences among the genotypes were observed for cane yield and yield contributing parameters and sugar yield. Plant crop attained more cane yield, CCS% and sugar yield as compared to ratoon crop. The traits i.e., cane height and millable canes for plant crop while, cane girth and millable canes for ratoon crop showed strong significant relationship for enhancing cane yield. Insect pest infestation stated that attack in ratoon crop was remained 20.32% higher than plant crop. Stem borer accounted high infestation followed by top shoot and root borer among the genotypes. The genotypes HoTh-402, HoTh-404, HoTh-408, HoTh-409, HoTh-414 and HoTh-430 on account of their better performance were selected for further testing and progression in final selection trials. The selected genotypes have great promise to be good commercial varieties in future (Chohan *et al.*, 2014).

Two genotypes HoTh-434 and HoTh-424 were remained highly susceptible to the sugarcane borer complex infestation accounted (13.63 and 11.24 % attack, respectively) followed by the local check variety BL-4 which fall in the susceptible category with 10.54% attack. While the genotype HoTh-438 (8.75%) and HoTh-419 (8.73%) remained less susceptible. The rest genotypes remained resistant to borer complex attack. The results for ratoon crop revealed that three genotype HoTh-434, HoTh-424 and HoTh-419 were remained highly susceptible to the sugarcane borer complex infestation (16.66, 15.60 and 12.50 % attack, respectively). The genotype HoTh-406 fall in susceptible category with 10.81 % attack and the local check BL-4 was remained moderately susceptible with 9.56 % attack. While the Thatta-10, HoTh-432 and HoTh-438 showed 8.73, 8.32 and 8.18% infestation respectively, and remained less susceptible to borer attack, respectively. The rest of the genotypes remained resistant to borer attack (Chohan *et al.*, 2014).

Santanu (2006) conducted experiment to determine the losses caused by stalk borer, *C. auricilius* and plassey borer, *C. tumidicostalis* in six recommended sugarcane cultivars (Bo 120, Co 687, Co 95422, BO 91, BO 128 and Co 92423) during 2003-2004, 2004-2005 and 2005-2006 in Bethuadahari, Nadia, West Bengal, India and observed that Co 687 (7.14%) and Co 92423 (4.93%) recorded the lowest reduction in single cane weight caused by stalk borer and plassey borer. Co 95422 (2.05%) and var. B) 120 (6.73%)

recorded the lowest reduction in cane yield. Co 92423 recorded the lowest (0.48%) cane yield reduction caused by plassey borer.

Abdullah *et al.* (2006b) in a field experiment was observed the response of six promising sugarcane clones (I 245-99, I 262-99, I 429-99, I 433-99, I 446-99 and I 486-99) and two standard cultivars (Isd 20 and Isd 32) to some major insect pests. Results revealed that top shoot borer, *Scirpophaga excerptalis* and stem borer, *C. tumidicostalis* infestation ranged from 4.55 to 53.58% and 5.25 to 55.21%, respectively, with the highest (53.58%) and 55.21%) level of infestation being observed in clone I 429-99 among the tested clones.

Khanzada (2002) reported that fifty varieties of sugarcane were screened for their relative degree of tolerance and susceptibility against top shoot and stem borers attack during two consecutive autumn seasons i.e., 1990-91 (plant) and 1991-92 (ratoon) crops, to determine the impact of related intensity of borer infestation in both the crops. It is concluded from the study that highly significant variation due to borer damage were recorded for cultivars. None of the variety recorded is immune to the borer attack. A classified varietal behavior according to the borer infestation of both the plantations was also recorded.

Kalita and Gupta (2001) studied ovipositional preference of Trichome of ten sugarcane clones by plassey borer, *Chilo tumidicostalis* in a choice test in the laboratory at Assam Agricultural University, Jorhat, Assam. Number of eggs was laid on clone 'Ekora kuhiyar'. The percentage of leaf oviposited was the lowest (5.56%) in 'WL 22' and the highest (34.92%) in 'Jathipatia'. The mean number of egg masses laid (2.33) and the mean number of eggs oviposited was the highest (364.33) in 'Jathipatia'. The clone 'WL 22' had the lowest (0.33) mean number of egg masses and mean numbers of eggs oviposited (67.33). ‘Ekora kuhiyar’, was not preferred because of high numbers of spines on the eadaxial leaf surface while ‘Jathipatia’ was of the non-pubescent type. The clone ‘WL 22’ had long spines. Length of trichome was significantly negatively related (r = -0.68) and density of trichome was negative but non-significantly related (r = 0.56) with ovipositional parameters by plassey borer.

Thirumurugan *et al.* (2000) screened seventeen sugarcane clones under field conditions at Sugarcane Research Station, Melalathur during 1998-99, for resistance to shoot borer and internode borer. Four clones (G. 93008, G. 93010, G. 92394 and Si. 89084) were moderately susceptible to shoot borer and less susceptible to internode borer, and two clones (G. 93003 and G. 92392) were moderately susceptible to both shoot and internode borer in sugarcane crop.

Pandey *et al.* (1997) tested 23 varieties and reported that 16 varieties of the whole set of cultivars were below 15% infestation ranging from 5.76% in CoS 93422 to 14.88% in CoS 92234. The stem borer infestation in 6 varieties were observed from 15.23% in UP 22 and 28.70% in CoS 767. These were classed moderately resistant. Only Co 1148 was susceptible (30.10%) to stem borer attack.

Pandey *et al.* (1994) noted that out of two hundred and forty accessions of sugarcanes, twelve were found resistant against *C.tumidicostalis.* Suhartawan (1993) reported that amongst ten varieties of sugarcane, POJ 3061, PS 56 and M 442-51 were moderately resistant to *C. tumidicostalis*. Padmanabhan *et al.* (1990) conducted experiment with 31 sugarcane clones and six standard cultivars for resistance to pests and reported that 31 entries were resistant and 5 moderately resistant and 1 susceptible to *C. tumidicostalis.*

2.8.1.3.1 Morphological resistant factors of sugarcane genotypes

2.8.1.3.1.1 Stem hardiness and fiber content

Sugarcane yield is the product of quantitatively inherited phenotypic traits viz., number of millable cane, stalk length, stalk diameter, stalk weight, leaves length, cane yield and stem hardness (Ahmed*et al*., 2010, Khan *et al*., 2007). High fiber content and stem hardness and possibly with higher levels of pith in varieties refers to low insect damage (White *et al.,* 2006). Negative correlation between internodes stem hardness and sugarcane borer incidence exists (Martin*et al*., 1975). Sugarcane borer resistant clones increases the frequency of ideotypes with high fiber, pith, tight leaf sheaths and increased stem hardness of immature internodes (White*et al*., 2006). The correlation between stem hardness with fibre percent cane is more significant and fiber % cane is significantly associated with insect resistance (Keeping and Rutherford, 2004). Percent infestation of *C. tumidicostalis* was found positive correlation with percent fiber in cane (Ahmed and Khan, 1991; Rahman and Alam, 1987 and Kumar *et al*., 1972) but negatively correlation with percent reducing sugar and percent fiber in cane (Rahman, 2013).

The lower fiber percentage is necessary for better sugarcane production (Islam, 1984 and Jabber *et al*., 2005). Islam (1984) reported that higher fiber content leads to higher baggasse production and pol losses in baggasse. Jabber *et al*. (2005) also reported that minimum fiber content in I 22-94 (18.69%) followed by I 122-95 (18.64%). The minimum infestation of stem borer was observed in the varieties where fiber percentage was higher (Rahman, 2013). He found that fiber content was minimum (14.38%) in Isd 38, having no significant variation from Isd 40, where higher (9.45%) infestation occurred followed by Isd 40 (9.47%).

2.8.1.3.1.2 Pith content

White *et al*. (2006) reported that varietal resistance is an important component of the integrated pest management program for controlling damaging infestations of the sugarcane borer. Developing borer resistant varieties is, however, hindered to some extent by lack of general knowledge of resistance selection strategies. They investigated the association of sugarcane pith with sugarcane borer resistance within a population of progeny selected from a biparental cross. The population consisted of 15 clones selected with pith and 15 clones selected without pith. These selections were planted in a replicated experiment to evaluate their response to borer feeding. Damage was measured as percent bored internodes and damage ratings in both the plant-cane and first ratoon crop. They found that the sub-population with pith sustained fewer damaged internodes (pith = 12.5 %; no pith = 15.6 %) and had lower damage ratings (pith = 3.7; no pith = 4.0) than the subpopulation without pith; however, these differences were not significant when selection was considered as a random effect in our statistical model. Pith in the upper portion of the stalk was negatively correlated with damaged internodes and ratings in first ratoon. Within each subpopulation, there were individuals that were both resistant and susceptible suggesting that factors other than the presence or absence of pith were contributing to resistance. Two other factors that were investigated, target-internode rind hardness and fiber content, were more closely associated with resistance than pith. Fiber content was correlated with resistance in all cases. Pith was not correlated to stem hardness and fiber content. Phenotypic selection in the early stages of variety development for low insect damage may result in varieties with high fiber content and rind hardness, and possibly with higher levels of pith. Accumulating these traits through repetitive phenotypic selection during recurrent selection may account for the lower sugar yields often observed in borer resistant selections. Higher levels of pith in varieties refer to low insect damage (White *et al.,* 2006).

2.8.1.3.1.3 Sugar content

2.8.1.3.1.3.1 Brix perncentage

Percent infestation of *C. tumidicostalis* was found positive correlation with Brix percent in cane (Ahmed and Khan, 1991, Rahman and Alam, 1987; Kumar *et al.* 1972). The percent infestation, yield potential, loss in weight and loss in sugar recovery the package (Comprising planting of borer free sett + removal of primary stem borer infested cane + de-trashing in June through September + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August) was judged as the most effective, profitable (Rahman *et al*., 2015) and highest (22.33%) brix was recorded by Islam *et al*. 2013.

2.8.1.3.2 Biochemical resistant factors

2.8.1.3.2.1 Pol percentage

Percent infestation of *C. tumidicostalis* was found positive correlation with pol percent cane (Rahman, 2013; Ahmed and Khan, 1991; Rahman and Alam, 1987 and Kumar *et al.*, 1972).

2.8.1.3.2.2 Amount of reducing and non-reducing sugar

Percent infestation of *C. tumidicostalis* was found positive correlation with percent reducing sugar (Ahmed and Khan, 1991; Rahman and Alam, 1987; Kumar *et al*., 1972), but negatively correlation with percent reducing sugar in cane (Rahman, 2013). The lowest reducing sugar is desired for sugarcane production under commercial field condition (Chen, 1985 and Beniwal *et a*l., 1989). They observed that reducing sugar was minimum (10.92%) in resistant clone of Co7314 and maximum (89.33%) in highly susceptible clone of S 78/560.

2.8.1.3.2.3 Nutrient effect

The presences of different nutrient elements in sugarcane leaves influence stem borer infestations (Afolobi, 1988; Bokhtiar and Sakurai, 2003 and Dang *et al.*, 1995). Chemicals and morphological characters of sugarcane plants have both attracting and repelling effect on pests.

2.8.1.3.2.3.1 Nitrogen (N_2) content

Infestation of sugarcane stem borer is positively correlated with total nitrogen content in sugarcane leaves (Wood, 1984; Abayomi, 1987; Rahman *et al.*, 1992; Banger *et al.*, 1994). Saikia *et al.* (1994) studied the infestation of the pyralids *Scirpophaga exceerptalis* and *C. tumidicostalis* in an experiment involving three sugarcane varieties at six levels of nitrogen in Asam, India during 1987-88 and observed that incidence of *S. excerptalis* increased with increased levels of nitrogen application. The lowest (5.56%) incidence of the pyralid was recorded at 0 kg N ha^{-1}. There was no significant effect of nitrogen levels on *C. tumidicostalis.*

2.8.1.3.2.3.2 Phophorous (P) content

Infestation of sugarcane stem borer is positively correlated with total phosphorus content in sugarcane leaves (Wood, 1984; Abayomi, 1987; Rahman *et al.* 1992; Banger *et al.*, 1994).

2.8.1.3.2.3.3 Potassium (K) content

Infestation of sugarcane stem borer is negatively correlated with total potassium content in sugarcane leaves (Rahman, 2013).

2.8.1.3.2.3.4 Silicon (Si) content

Calatayud *et al.* (2016) reported that silicon is a relatively inert element that rarely occurs freely in nature. Silicon, the second most abundant element on earth, frequently occurs in plants in its oxidized form, silicon dioxide (SiO_2), commonly known as 'silica'. In soils, Si is mainly present as quartz, alkaline earth or aluminium silicates (Paul, 2007). Although these forms of silicon are both chemically and biologically inert, they are reported to significantly influence the physical properties of soils including soil texture, water holding capacity and fertility (Conley, 2002). Si content in soils ranges between 20-35% for clay or silt to 40-44% for sandy soils (Essington, 2003). Although the element is abundant in most soils worldwide, it is rather sparse in weathered tropical soils.

Liang*et al.* (2015) reported that silicon (Si) is involved in plant resistance against insect pest damage via two major defense mechanisms: physical defense and induced biochemical (chemical) defense. Si deposited as opaline phytoliths within plants may act as an anti-herbivore defense through increasing hardness and abrasiveness of tissues and wearing of herbivore mouthparts. In turn, this would create a feeding deterrent, which may reduce the palatability and digestibility of leaves, thereby potentially impacting on herbivore performance (physical defense). On the other hand, increasing evidence shows that biochemical changes and induced resistance, because of Si uptake by the plant, are also responsible for the alleviation of insect pest damage. More recently, it has been confirmed that Si plays a positive role in priming plants for a better defense response against pest infestation (e.g., rice leaf roller). The protective effect of silica to plants against insect herbivores is related to the level of its accumulation and polymerization in plant tissues with highest levels positively being correlated with increased resistance (Juma *et al*., 2015; Laing *et al*., 2006; Bélanger *et al.*, 2003). In addition, the level of Si in plants significantly influences insect herbivores distribution with predominance of insect species being more susceptible to areas where most host plants are less silicified (Calatayud *et al.*, 2016). However, exact mechanisms of action of silica on herbivorous insects are still unclear, though most studies point to use of both physical and/or chemical resistance mechanisms (Ma, 2004; Fauteux *et al*., 2005). Mechanically, deposition of silica in plant epidermal cells provides a physical barrier against insect's probing and feeding or insect's penetration into plant tissues. For example, silica mediated stem borer resistance to *Eldana saccharina* (Walker) (Lepidoptera: Crambidae) on sugarcane or *Chilo suppressalis* Walker (Lepidoptera: Crambidae) on rice has been partly associated with delayed stalk penetration by larvae as a result of leaf and stalk silification (Djamin and Pathak, 1967; Kvedaras, 2007). Silica may also alter the relative palatability of leaves by increasing leaf abrasion, which increases wearing of insects' mandibles and therefore physically deter larval feeding (Raupp, 1985; Massey *et al.*, 2006). On the other hand, silica in plants has been shown to modulate the production and accumulation of herbivore defensive allelochemicals including phytoalexins, lignin and phenolics in plant tissues (Belanger *et al*., 2003; Cherif, 1994 and Borel *et al*., 2005). Similarly, silica is also reported to elicit the production of plant defensive enzymes including peroxidase, polyphenoloxidase and phenylalanine ammonia lyase which are induced in response to plant damage by herbivorous insects (Keeping and Meyer, 2002; Correa *et al*., 2005 and Gomes *et al*., 2005). These enzymes have been implicated in a number of plant defenses processes such as lignification and/or production of antiherbivore plant metabolites (Felton, 1994).

McGinnity (2015) reported that Silicon (Si) has long been known to provide beneficial effects on soil and plant growth. There is a significant collection of scientific literature that supports the beneficial effects of Si when incorporated into agricultural practices on a wide variety of crops. Most scientists and state regulators do not yet consider Si as an essential nutrient for plant growth. However, Si has recently been recognized as a beneficial substance by The Association of American Plant Food Control Officials (AAPFCO). This review of existing papers and research will outline the current knowledge base surrounding The role that Si plays in plant nutrition, soil composition and quality, stress tolerance to Abiotic and biotic factors and the metabolism of Si within the plant.

The application of Si derived from natural silicates has been shown to reduce the effects of environmental stresses on a plant as well as make more efficient use of soil and fertilizer nutrients such as nitrogen and phosphorous. Crops are divided into two groups when one discusses Si utilization by a plant. There are Si accumulators, where Si is greater than 1% of a plant's dryweight and Si non-accumulators, where the Si is less than 1% of a plant's dry weight. Seven of the ten mos planted crops in the world are Si accumulators. Most researchers believe that silicon (Si) is taken up as monosilicic acid (H_4SiO_4) and moves in the xylem and the phloem of a plant's vascular tissue. Once in the plant the Si tends to from amorphous silica particles called phytoliths.The mode of action is still not completely understood and researchers are in disagrement to the active or passive nature of phytolith formation (McGinnity, 2015).

The role that Si play in reducing the impact on plants from abiotic and biotic stresses such as drought, disease and insect stressse, have been well documented across crops. Si functions in many different ways within a plant and mostreseachers believe it is a combination of multiple Si effects that allow plants to better tolerate the many stress factores a plant is exposed Soil applications of Si have also been demonstrated to reduce the toxicipact from high levels of metals in the soil including managanese, cadmium, cupper and arsenic. Si levels in the soil and the role Si plays in plant metabolism and stress management.

Vasanthi *et al*. (2014) mentioned that the role of silicon in pest control was reviewed recently (Laing *et al*., 2006). A cursory perusal of the available literature indicates that higher silica content reduced the incidence of several crop pests. (Rice: stem maggot; green leaf hopper; brown plant hopper; white backed plant hopper; stem borer; African striped borer; yellow stem borer; leaf folder; gall midge, wheat: green bug; hessian fly whitefly. maize: stalk borer; borer; leaf aphid; European corn borer; army worm, sorghum: green bug, sugarcane: shoot borer; stem borer; African stalk borer, musk melon: fruit fly, Zinia: aphids).

Vasanthi *et al*. (2014) also reported that silicon is accumulated in plants higher than the essential major nutrients. Although it is not considered as an essential element it is accepted as an agronomically beneficial element as it confers rigidity and strength, resistance against pests and diseases, improves water economy by reducing transpiration rate, alleviates the ill effects of abiotic stresses and enhances crop yield. Its continuous removal from soil by cropping is left unreplenished and hence the demand for silicon by crops escalates when other fertilizers are applied. As silicon nutrition reverses the succulence induced by high nitrogen and enhances crop growth and yield silicon fertilizers based on silicate minerals, ashes and slags have come into vogue. Solubilizations of silica in situ in soil by silicate solubilizing bacteria to supplement crop need are also made. The role of silicon nutrition in crop production and crop protection are reviewed.

Laing *et al.* (2006) reported that responses to silicon application in reducing pest populations and plant damage are usually more obvious in susceptible than resistant varieties. Silicon depositions in monocots may provide a mechanical barrier against insect pests. However, this passive role of silicon is now being contested and an active role of silicon has been shown in the physiological resistance of crops to diseases. Silicon is now considered to have a catalytic role in the expression of physiological resistance through the production of among other chemicals, tannic and phenolic compounds. The application of silicon in crops provides a viable component of integrated management of insect pests and diseases because it leaves no pesticide residues in food or the environment, and it can be easily integrated with other pest management practices, including biological control. Applications of Si also appear to reduce insect activity on crops. This suppression includes pests such as stem borer and arrange of leaf hopper and spider mites (Savant *et al*.,1997).

2.8.2 Mechanical control

Anwar *et al.* (2004) reported that use of iron nets for moths collection and cutting of 2-3 unripened internodes along with tops infested with gurdaspur borer, pulling out of dead hearts and killing of larvae of borers with iron bars impregnated with insecticides ensured successful control of the pest. Hashmi (1994) suggested that sugarcane borer infested parts should be cut and fed to cattle and earthing up are the best control measures for gurdaspur borer, *Acigona steniellus* in sugarcane.

2.8.3 Chemical control

Abdullah *et al*. (2005) conducted different studies with Cartap 4G insecticides Seda 50SP, Padan 50SP, Cidan 4G, Razex 4G, Forwatap 4G, Sudan 4G and Padan 4G to evaluate their effectiveness against stem borer of sugarcane during 2001-2002 cropping season. Higher pest control was achieved with the higher number of application of chemicals. It was found that Cidan 4G, Razex 4G, Forwatap 4G and Sundan 4G @ 3.0

kg a.i. ha^{-1} applied in June, July and August effectively controlled stem borer of sugarcane. An increase of 28.86 to 50.61% in yield was recorded in insecticide treated plots as compared to untreated ones, respectively.

Abdullah *et al.* (2005) conducted another field experiment to evaluate the effectiveness of three cartap insecticides viz., Tenup 50SP, Forwatap 50SP and phartap 50SP at different doses and frequencies of application for the control of sugarcane stem borer, *Chilo tumidicostalis* Hampson at 3 locations in the cropping season of 2003-2004. All the test chemicals significantly controlled stem bore but could not show desired level of effectiveness (over eighty percent) over control in any location. Only standard Cidan 4G showed more than 80% effectiveness over control in all the locations, treated plots showed increased cane yield (22.32%) over control.

Alam *et al.* (2005) reported that Cidan 4G, Razex 4G, Forwatap 4G and Sundan 4G @ 3.0 kg a.i. ha^{-1} applied in June, July and August effectively controlled stem borer of sugarcane. Tunkhumtong (2003) noted that the population of sugarcane moth borer *C. tumidicostalis* was lower during the first four months of sugarcane and the population increased there after. The population of *C. tumidicostalis* increased during the last six months of sugarcane, its population was low during the young shoot stage. The changes of population structure in terms of age structure were determined at Doembang Nangbuat, Thailand in 2001-2002. It was obvious that the adults of *C. tumidicostalis* moved into the sugarcane field during the elongation stage. The egg population was high in July and August 2001 and lowest in February to April and December to January. In June to August the population consisted of larger instars larvae and pupae, and every stage of *C. tumidicostalis* was found during July and August in 2001.

The investigation on biology of *C. tumidicostalis* revealed that the oviposition period of *C. tumidicostalis* was 1.91±0.69 days, ranging from 1 to 3 days. The number of egg laid per female averaged 123.31±70.89 eggs, ranging from 5 to 250 eggs. The incubation period was 5.28±0.85 days, ranging from 4 to 7 days. The larvae of *C. tumidicostalis* molted five to seven times before pupation, the total larval periods of *C. tumidicostalis* with five, six and seven larval instars were 24.67±4.07, 33.43±4.46 and 37.3±2.76 days respectively. The full-grown larvae of *C. tumidicostalis* pupated in the larval tunnels or in the leaf sheath of sugarcane. The pupal staged took about 5 to 9 days. The longevity of male and female was 2 to 5 and 2 to 5 days, respectively. The total life cycle from egg to adult of *C. tumidicostalis* with the five, six and seven instars larvae periods was 45.87±3.58, 54.57±4.55 and 58.13±3 00days respectively.

Talpur *et al*. (2002) conducted to assess the chemical control of sugarcane stem borer at Agricultural Research Institute, Tandojam during 1999-2000. Four insecticides namely Furadan 3G (carbofuran) at 4.86 kg ha^{-1}, padan 4G (cartap) at 3.64 kg ha^{-1}, Basudin 10G (diazinon) at 3.64 kg ha^{-1} and Thimet 5G (phorate) at 4.05 kg ha^{-1} and compared with and untreated (check plots). All insecticides resulted minimum infestation percentage of stem borer significantly at 10, 15 and 30 days of post treatment and increased cane yield over check plot. Among the best products Furadan proved superior in checking stem borer infestation over rest of the product tested.

Afzal *et al*. (1996) reported that Gurdaspur borer was a serious insect pest, played havoc with the sugarcane crop in the late stages. For the control of this insect pest, three granular insecticides (Curater 3G, Diazinon 10G and Furadan 3G) at 6.07 kg ha^{-1}, one biological insecticide (Bt powder formulation of *Bacillus thuringiensis*) at 202 g ha^{-1} along with mechanical de-topping were applied to observe their comparative efficacy.

The mechanical detopping gave significant reduction in the infestation (0.32%). Cureter and Furadan 3G gave 25.64 and 23.79% larval mortality, respectively while Diazinon 10G, Bt and untreated control should no larval mortality.

Khan and Jan (1994) revealed that Sevidol 4G, Curater 3G and Basudin 10G @ 25 kg ha^{-1} when applied as side dressing followed by earthing-up reduced the stem borer infestation to 2.81, 7.34 and 17.89% respectively but also increased the average cane yield up to 56.88, 56.62 and 44.31 tons ha^{-1} along with higher sugar yield of 7.86, 7.39 and 5.95 tons ha^{-1} respectively. Rana *et al.* (1992) noted that Furadan 3G and Curater 3G @ 4.86 kg ha-1 applied as side dressing followed by earthing-up of cane crop not only reduced average cane borer infestation to 3.00 to 3.11% but also increased the stripped cane yield up to 11.67 -11.83 tons ha^{-1}.

Shajahan *et al*, (1983) who conducted the field trials during 1973-78 to control stem borer using Padan 4G, Orthene 5G, Monitor 500, Furadan 3G, Sevidol 8G, Basudin 10G, Fendal 5G, Cytrolane 10G, Disyston 10G, Sevin 5G, Terracur 5G, Dursban 20EC, Supracide 40EC, Azodrin 10EC and Nuvacron 40WSC; but none of them reached the desired level of control of stem borer. In 1979-80, they also conducted study utilizing Tyfanon 57EC, Nogos 100EC and Carbicron 10WSC; but none showed significant control of the pest. But Padan 4G (under Cartap group) gave promising results in controlling stem borer. Results revealed that insecticides of Cartap group provided effective control of the pest (Shajahan *et al.*, 1983).

2.8.4 Integrated Pest Management (IPM)

Rahman *et al*. (2015) evaluated the effectiveness of some IPM components to develop effective package(s) for suppressing stem borer infesting sugarcane. The eight components of IPM packages singly or in combinations were used for this purpose. Package 1= Comprising planting of borer free sett, Package 2 =Composed of removal of primary stem borer infested cane, Package 3 =With planting of borer free sett + removal of primary stem borer infested cane, Package 4 = Detrashing in June through September, Package 5 = Comprising planting borer free sett + removal of primary stem infested cane + detrashing in June through September, Package 6 = Comprising Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August, Package 7 = Composed removal of primary stem borer infested cane + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August, Package 8 = Comprising planting of borer free sett + removal of primary stem borer infested cane + detrashing in June through September + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August and Package 0 =Untreated control). In November, the highest 82.46% infestation reduction was obtained in the package 8 consisted of Comprising planting of borer free sett + removal of primary stem borer infested cane + detrashing in June through September + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August followed by package 7 (79.07%) with highest yield of 72.33 ton ha^{-1} in package 8 followed by package 7 using Composed removal of primary stem borer infested cane + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August (67.63 t ha^{-1}). The minimum loss in weight was obtained from package 8 (1.91%) followed by package 7 (3.91%). The lowest sugar recovery loss was found in package 8 (0.93%) followed by package 7 (3.70%) and package 6 (5.56%). The highest (2.09) BCR was obtained from package 8. The second highest (1.97) BCR was obtained from package 7 followed by package 6 Comprising Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August (1.95). The lowest (1.38) BCR was found in untreated control plot. Considering the percent infestation, yield potential, loss in weight, loss in sugar recovery and BCR, the package 8 was judged as the most effective, profitable and recommendable to fit the IPM component for managing of sugarcane stem borer.

Ahmad *et al.* (2011) evaluated some environmentally sound tactics for the management of sugarcane stem borer (*C. infuscatellus*). Different approaches applied were: T*richogramm*a cards, detrashing, light traps and chemical control. The effects were evaluated on the basis of incidence and intensity of *C. infuscatellus*. It was concluded from the results that the minimum infestation (8.71%) was recorded in package 7 (Trichogramma cards + detrashing + light traps) treated plot which was statically comparable to those of package 3 (Trichogramma cards + light Traps), package 1 (Trichogramma cards + detrashing) and package 4 (Detrashing + chemical control) with increase in percent infestation 8.92%, 9.34% and 9.74%, respectively. The package 8 (Trichogramma cards + chemical control + light traps) showed 10.46% infestation and was significant different from package 6 (Trichogramma cards + detrashing + chemical control), package 9 (Chemical control + light trap +detrashing) with infestation rate of 11.66% and 11.86% respectively. The package 2 (Trichogramma cards + chemical control) with infestation 12.39% was statically at par with those of package 5 (Detrashing + light traps) with infestation of 12.82%. The maximum infestation was observed in untreated control plot resulting infestation of 25.45%. The minimum infestation (11.66%) was recorded when applied at 10 days interval while maximum infestation (12.53%) was observed at 20 days interval.

Munir *et al*. (2011) conducted best time of application of Carbofuran granules and to compare chemical and biological control against borers at Sugarcane Research Institute, Faisalabad during 2007-2009. Carbofuran 3G @ of 80kg ha^{-1} was applied to crop at different timings, starting from sowing to 135 days after sowing (DAS). The results revealed that split application of granules at sowing + 45-60 DAS + 90-135 DAS was equally effective against top shoot, stem and root borers. Forty, 50 and 63 *Trichogramma* cards ha^{-1} were used at 7 and 15 days intervals and were compared with granular applicantion of Carbofuran 3G. The granular application reduced borer infestation significantly, however, application of 63 *Trichogramm*a cards ha^{-1} weekly was also found effective against borer control. The control of top shoot borer by *Trichogramm*a cards was less effective than stem and root borer. It is concluded that *Trichogramma* cards can effectively control stem and root borers and granules may be applied against top shoot borer. The biological control approach is environment friendly and does not disturb the ago-ecosystem of natural enemies.

Rajendran (2006) evaluated the integrated pest management (IPM) programme against sugarcane borer which was practiced in New Delhi, India during 2002-200. The IPM components included sugarcane trash mulching on ridges after 3-5 day of planting, use of 20% more setts over the conventional sett rate of 75000 ha^{-1} for late season planting, irrigation once a week from the third to the tenth week, earthing-up after the second weeding and fertilizer application, de-trashing the cane during the fifth and seventh month of cultivation, release of egg parasitoid *Trichogramma chilonis* at 2.5 cc ha^{-1} 6 times at fortnightly intervals after 5 months of planting and harvesting at the 12 month without delay. This IPM programme increased the millable canes and yield of the crop by 36.45% and reduced the infestation of the crop by stem borers, *C. tumidicostalis.*

Khan and Khan (2006) reported that field experiments with IPM at Sugar Crops Research Institute, Mardan, Pakistan during 2000-2004 on sugarcane borers. They tested various IPM techniques i.e. cultural, mechanical and chemical control methods individually and in combinations. Results of 3 plant 3 ratoon crops revealed that treated plots significantly reduced shoot, stem, and root borers infestation compared to check plots. They further reported that combined application of IPM methods viz., mechanical + cultural + biological and mechanical + cultural + chemical control resulted in lowering borer infestation and highest cane yield (104.31 t ha^{-1}) with highest sugar yield (13.62 t ha^{-1}) especially in plant crop.

Kuniata and Sweet (2003) noted that *C. tumidicostalis* Hampson is a serious pest of sugarcane in New Guinea. Due to its attack annual sugar production losses ranged from 5-18%. They suggested that the control of *S. grisescens* requires integration of several cultural and biological methods. Owing to a sugarcane varietal interaction the time of planting and harvesting of heavily infested fields varied. Inundative releases of *Cotesia flavipes* though slowly established in the field gave up to 70% parasitism. The use of systemic insecticides such as carbofuran over several seasons was found ineffective in controlling *S. grisescens*. Pheromones are still being evaluated for population monitoring and may possibly be useful for mating disruption.

Jena *et al.* (1997) conducted field experiments in Qrissa, India during 1992-94 on sugarcane borer's control. They reported that earthing up in May to June, detrashing cane and removing infested shoots, applying fertilizers during the monsoon season, were effective for the control of stalk borer, *C. auricilius* attacking sugarcane variety Co 62175. Bessin *et al*. (1990) conducted a study to evaluate the contributions of arthropod predation, varietal resistance, and insecticidal control for the management of the sugarcane borer in sugarcane (a complex hybrid of *Saccharum* spp.). The study helped to quantify the value of multiple control tactics in pest management. Insecticidal control was the predominant factor preventing plant injury by the sugarcane borer, supplying <60% of the overall control. However, varietal resistance was almost as effective as insecticidal control at suppressing moth emergence and each contributing 42% and 47% control, respectively. Even a moderately resistant sugarcane variety, CP 65-357, substantially reduced moth emergence. However, the relative contribution of varietal resistance of CP 65-357 toward control was diminished in a year with high sugarcane borer population pressure. A significant interaction ($P < 0.05$) was detected between varietal resistance and insecticidal control, indicating greater insecticidal suppression of adult emergence on the susceptible and moderately resistant varieties than on the resistant variety. Despite this limited incompatibility, greater sugarcane borer control was always obtained with the incorporation of additional management factors. The resistant variety, CP 70-330, was shown to have a reduced potential for yield loss with the removal of insecticidal control. This study showed that the importance of a particular management tactic was increased when the relative contributions of other control tactics were reduced. Additionally, greater increases in sugar yields were detected when insecticidal control was used in combination with arthropod predation than without predation.

Chapter III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Five experiments were conducted in the field and laboratory to achieve the objectives of the study seasonal abundance, varietal resistance and integrated management of sugarcane stem borer, *C. tumidicostalis* Hampson. The materials and methods include a short description of the experimental site, agro-ecological zone (AEZ), soil status, agro-meteorological features of the experimental area, materials used for the experiment, design and layout of the experiment, data collection and statistical analysis. The materials and methods adopted for different experiments are discussed here in:

3.1 Pest status and infestation intensity of sugarcane stem borer in major sugarcane growing regions in Bangaladesh

Pest status and infestation intensity of *C. tumidicostalis* on sugarcane in farmer's filed of major sugarcane growing regions in Bangladesh was surveyed in 2014 and in experimental fields at BSRI during 2014, 2015 and 2016. Farmers' information on sugarcane pests, their damage potentiality, pest status, control measures were collected through structured questionnaire and infestation intensity of *C. tumidicostalis* was recorded by direct survey of farmers' field from different regions. The materials and methods used for this experiment have been presented in this chapter.

3.1.1 Survey of farmers' information on pest status and infestation intensity of *C. tumidicostalis*

3.1.1.1 Duration of the study

The surveys and interviews with relevant respondents of major sugarcane growing areas in Bangladesh were conducted during July to August, 2014.

3.1.1.2 Study site

The study was conducted to cover intensive sugarcane growing regions in Bangladesh. To collect the information and present status of different insect pests of sugarcane in field, an extensive survey was conducted at 15 upazilas of selected 9 major sugarcane growing districts which covered 8 (eight) sugar mills under 6 agro ecological zones of Bangladesh such as 15 upzila of Rajshahi, Natore, Pabna, Kustia, Jhinaidah, Jessore, Joypurhat, Naogaon, Dinajpur districts which covered eight sugar mills such as Rajshahi Sugar Mills ltd (RJSM), Natore Sugar Mills Ltd (NTSM). Noth Bengal Sugar Mills Ltd (NBSM), Pabna Sugar Mills Ltd (PBSM), Carew and Company, Mobarakganj Sugar Mills Ltd (MKSM), Joypurhat Sugar Mills Ltd (JSM) and Setabganj Sugar Mills Ltd (STSM). The study districts and upazilas are presented in Table 3.1.1 and also in Figure 3.1.1.

Table 3.1.1 List of districts and upazilas selected for survey of insect pests of sugarcane in Bangladesh

Sl. No.	District	Upazila	
1	Rajshahi	1.	Puthia
		2.	Poba
2	Natore	3.	Natore
3	Pabna	4.	Ishordi
		5.	Pabna
4	Kustia	6.	Kustia
5	Jhenaidhah	7.	Kaliganj
		8.	Kotchadpur
6	Jessore	9.	Chougacha
		10.	Jessore
7.	Joypurhat	11.	Joypurhat sadar
8	Noagaon	12.	Dhamuirhat
9	Dinajpur	13.	Kaharol
		14.	Birol
		15.	Dinajpur sadar

3.1.1.3 Respondents of the study

The field survey was conducted to find out the present status of insect pests of sugarcane in the sampled districts of Bangladesh. The study was done through survey questionnaires and interviews with the relevant respondent (farmer). Sugarcane growers were interviewed using structured questionnaire to record the present status of insect pests of sugarcane, their damage and management practices.

Figure 3.1.1 Map of Bangladesh showing locations (★) from where data were collected.

3.1.1.4 Data Collection

3.1.1.4.1 Questionnaire

A comprehensive survey was conducted through interview of sugarcane growers and field visit during July to August, 2014 when peak infestation of stem borer occured. Farmer's interview was taken through structured questionnaire. For farmer's data collection, ten cane growers were randomly selected from 5 upazila and 5 cane growers were randomly selected from rest 10 upazila. Farmer's opinion was collected on age, education, sugarcane cultivation experience, training on sugarcane cultivation, major pests of sugarcane, their management practices, incidence of stem borer and its extent of damage through structured questionnaire. Data were processed and analyzed after survey.

3.1.1.4.2 Variables covered

Considering the study of objectives, the following variables were considered during development of questionnaire for data collection from the farmers.

1. Demographic : Name, age, sex.
2. Social : Education, profession.
3. Experience : Sugarcane cultivation experience, training.
4. Study related indicators:
    - Variety of sugarcane for cultivation;
    - Sources of seeds;
    - Name of pests attacking sugarcane in field;
    - Damage status/infestation intensity of the insect pests in field;
    - Management practices for the insect pests;
    - Damage status/infestation intensity of the pests;
    - Management practices for the pest;
    - Monetary loss due to insect pests attack;
    - Environmental problem due to use of chemical pesticides;

3.1.1.4.3 Development of study questionnaire

The draft questionnaires were prepared based on the objectives of the work and indicators for the study. The draft questionnaires were pre-tested in the selected study area and finalized (Appendix 3.1.1) with due care to be able to include appropriate questions for collection of necessary information from different levels and types of respondents to reflect the indicators relevant to the objectives of the study.

3.1.1.4.5 Methods of data collection

Direct personal interview approach was adopted for collection of sugarcane cultivation. Reaching the target area, farmers were selected with the help of sugar mill's personnels of that area. Then purpose of the interview and objectives of the study were described to the respondents. Lastly data sheet was filled up discussing with the respondents. After completion of filling up one questionnaire from one respondent, then moved to another respondent for fulfill the target respondents. The data were recorded only after fully being satisfied that the respondent was able to understand the question and offering any of the probable answers in his own perception. Efforts made done to have a friendly and open-minded interaction with the respondent instead of asking question like a school teacher to his students. All question had to ask one by one and data sheets were filled up on the spot by districts. As per sample design the 100 survey respondents had been interviewed for sampled 15 upazilas of nine major sugarcane growing districts under eight sugar mills zone.

3.1.2 Survey of *C. tumidicostialis* infestation in farmers' filed at major sugarcane growing areas of Bangladesh

Field data were collected from existing farmer's field of each surveyed upazila. Field data collection template has been shown in Appendix 3.1.2. Six sugarcane fields of different farmers were selected randomly from each upazila and 10 fields at BSRI farm area. A total of 100 sugarcane fields (90 fields from 15 upazilas and 10 from BSRI area) were selected for data collection. Three rows of sugarcane were selected randomly from each farmer's field. Five rows from the border of the filed were left to avoid border effect and 6^{th} row was selected as first row for data collection. Other two rows were selected alternatively after each five rows of the field. Then five plants from the border were left and hundred plants were examined continuously in each selected row. The number of healthy and stem borer infested plant were recorded separately for each row. Then healthy and infested internodes of each borer infested plant was observed and recorded. One infested plant from each row was cut longitudinally and number of stem borer larva was counted and recorded.

3.1.3 Study on infestation intensity of *C. tumidicostalis* in experimental plots at BSRI

3.1.3.1 Duration/Experimental period

The study was conducted to study the infestation intensity of C. *tumidicostalis* on sugarcane in three consequtive years 2014, 2015 and 2016 at BSRI in Ishurdi, Pabna.

3.1.3.2 Location/Experimental site

The experimental site was located at the experimental farm of Bangladesh Sugarcrop Research Institute (BSRI) between 24.80^0 North latitude and 89.40^0 East longitudes with an elevation of 15.5 meter from the sea level (Anon., 2011).

3.1.3.3 Agro-ecological zone (AEZ)

The experimental field belongs to the active Ganges flood plain corresponding Agroecological zone (AEZ)-10 and is dark grey to brown flood plain soil (Figure 3.1.2).

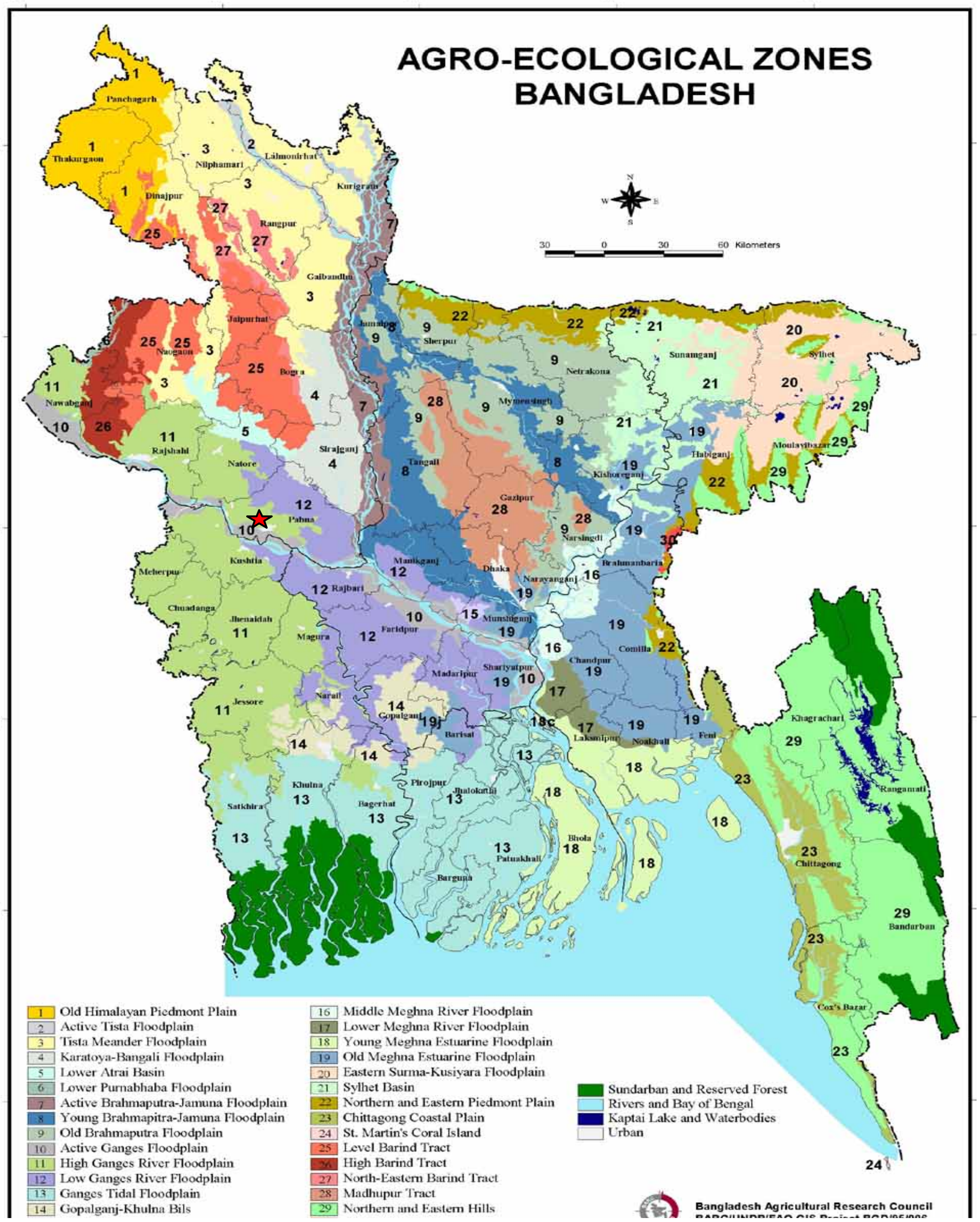


Figure 3.1.2 Map showing the location (★) of the experimental field in Agro Ecological Zone (AEZ) of Bangladesh.

3.1.3.4 Soil

Morpholigical and physiochemical properties of soil in experimental filed were analyzed at BSRI laboratory before setting the experiment.

3.1.3.4.1 Morphological characteristics

The soil of the experimental field was sandy loam in texture and slightly alkaline in nature with the P^H of around 7.65 and poor fertility status (Annual report, 2015) showing in Table 3.1.2.

Table 3.1.2 Morphological characteristics of the experimental field 2014

Morphological features	Characteristics
Location	BSRI Experimental farm, Ishurdi, Pabna
AEZ	Active Ganges flood plain -10
General Soil Type	dark grey to brown flood plain soils
Land type	Highland
Topography	Plain land
Flood level	above normal flood level
Drainage	Well drained
Textural class	Sandy loam
Bulk density	1.65 g cm^{-3}
Particle density	2.69 g cm^{-3}

3.1.3.4.2 Analyses of soil chemical properties

3.1.3.4.2.1 Physico-chemical properties

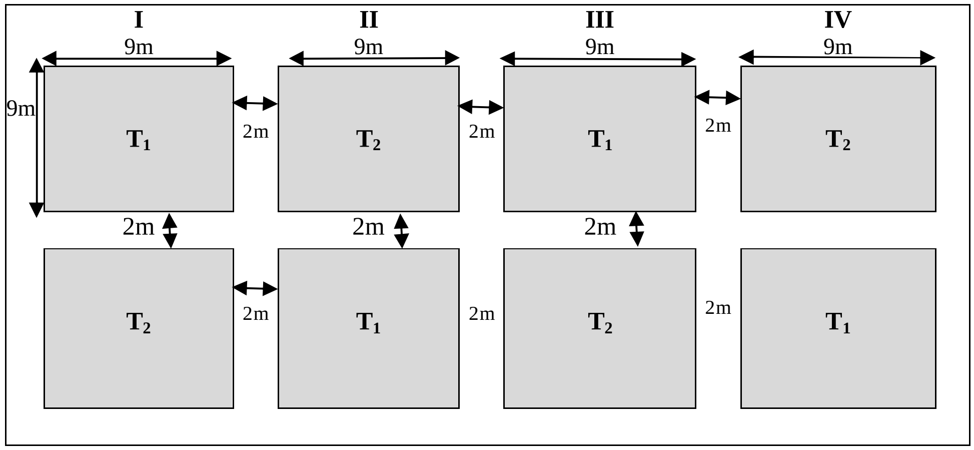
Before setting up of the experiment, soil samples were collected from the field which was used to fill the experimental pots. A Physico-chemical property of soil of experimental field was analyzed in the Soil and Nutrition Laboratory of BSRI, Ishurdi, Pabna (Annual report, 2015) shown in Table 3.1.3**.**

Table 3.1.3 Physico-chemical properties of the experimental soil during 2014

Characteristics (0-15 cm soil depth)	Value	Methods employed
% Sand	42.84	Hydrometer method (Black, 1965)
% Silt	48.00	Do
% Clay	9.16	Do
Soil P^H	7.65	Glass electrode P^H meter (Jackson, 1962)
Organic carbon (%)	0.60	Wet oxidation method (Page *et al.*,1982)
Organic matter (%)	1.03	Wet oxidation method Page *et al.*,1982
Total N (%)	0.06	Kjeldahl method (Bremner and Mulvaney, 1965)
Available P (ppm)	8.00	Olsen and Dean, 1965
Available Sulfer (ppm)	25.00	Calcium dihydrogen phosphate extraction (Hunter, 1984)
Exchangeable K (meq/100 g)	0.26	N NH_4OAc extraction (Pratt, 1965)
Exchangeable Ca (meq/100 g)	12.00	N NH_4OAc extraction
Exchangeable Mg (meq/100 g)	0.89	N NH_4OAc extraction

3.1.3.5 Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications in the field of the Entomology Experimental Farm of BSRI. The whole field was divided into four blocks consisted two (02) plots of equal size (9.0 m × 9.0 m) having two (2.0) m space between the blocks and plot to plot. Thus, the total number of plots was eight. The layout for this experiment is shown in Figure 3.1.3.



Plot size: 9.0 m × 9.0 m
Plant spacing: End to end of the sett
Block to block distance: 2.0 m
Plot to plot distance: 2.0 m

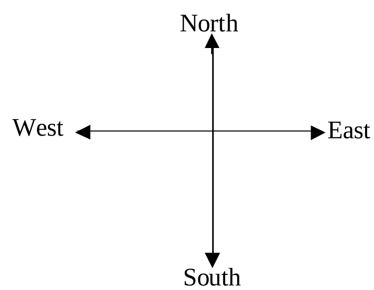


Figure 3.1.3 Layout of the experiment with two treatments and four replications.

3.1.3.6 Treatments

Two treatments use: $\mathbf{T_1}$ **=** cut and removal of all stem borer infested cane after data collection and $\mathbf{T_2}$ **=** keep the infested cane in the filed after data collection.

3.1.3.7 Soil preparation

Soil of the experimental plot was prepared by ploughing three (3) times and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth before 20 days of trench preparation. Weeds and other stubbles were removed carefully and finally prepared with the addition of basal dose of cow-dung in the experimental plots.

3.1.3.8 Trench preparation

Trench method was applied for sugarcane cultivation, and about 20.0 cm deep and 9.0 cm width trenches were made after the desired ploughing of soil maintaining a distance of 1.0 m between the rows. Soil at bottom of trench was loosened manually by spade (Figure 3.1.4). Trench method was used to protect the crop from lodging.

A. Block wise plot separation B. Trench preparation

Figure 3.1.4 (A) Block separation and (B) trench preparation for set placement in this experiment.

3.1.3.9 Manuring and fertilization

Manure and fertilizers were applied in the experimental field as per recommendation of BARC (2005). Doses of manure and fertilizers are shown in Table 3.1.4.

Table 3.1.4 Doses of manure and fertilizers used in experiment (BARC 2011)

Manures / Fertilizers	Doses hectare^{-1}	Quantity required
Cow-dung	10.0 tons	1.0 tons
Urea	358.0 kg	35.80 kg
Triple Super Phosphate (TSP)	275.0 kg	27.50 kg
Muriate of Potash (MP)	240.0 kg	24.00 kg
Gypsum	166.0 kg	16.60 kg
Zink Sulphate ($ZnSO_4$)	7.0 kg	0.700kg

The full quantity (1.00 ton) of cow-dung was applied as basal dose during land preparation. Fertilizers were used in different installments. Urea (35.80 kg) and MP (24.00 kg) were applied in three equal installments. Total amount of TSP (27.50 kg), Gypsum (16.60 kg), Zink Sulphate (0.700 kg) and one third MP (8.00 kg) were applied in trenches and thoroughly mixed with soil prior to sett placing. First installment of urea (11.93 kg) was applied in the setting establishment stage. Two third amount of MP (16.00kg) and urea (23.87 kg) were applied as first and second top dressing at tiller completion stage (90 DAP) and grand growth phage (180 DAP) (Days after planting), respectively. Top dressing of fertilizers was done at root zone in furrows prepared on both sides of rows and then covered with soils.

3.1.3.10 Planting material

3.1.3.10.1 Sett collection

Cane of sugarcane variety Isd 39 was collected from Breeding Division, Bangladesh Sugarcrop Research Institute (BSRI). The variety was released in 2009 from BSRI, Ishurdi, Pabna and its parentage was BC_5× Isd 25 [BC= Back Cross].

3.1.3.10.2 Sett preparation

Healthy, vigor, pest and disease free cane was selected from the upper two third portion of the stem. Then the cane was cut as such that each sett contained two buds. Rooted setts and damaged buds were separated from healthy setts.

3.1.3.10.3 Sett treatment

The setts were dip in Bavistin solution (1:1000) for 30 minutes to disinfest the sett born fungal disease and to prevent soil born fungal disease (Talukder*et al.*, 2005).

3.1.3.10.4 Sett placement

Two budded pre-germinated setts were planted end to end in trenches in the main field (Figure 3.1.5) through conventional sett placement method (Matin *et al.*, 1989).

A. Setts treatment with Bavistin solution (1:1000)   B. Setts placement in trench

Figure 3.1.5 Setts treated with Bavistin solution and placement of setts in the trench.

3.1.3.11 Intercultural operation

Intercultural operations such as gap filling, irrigation, weeding, mulching, earthing-up and tying were appropriately done throughout the cropping season to facilitate proper growth and development of canes (Rahman and Pal, 2003). Light irrigation was given at 7 days interval for proper germination of sett. Crust of surface soil inside the trenches was broken twice at 30 and 60 days after set placement for loosening the soil, to prevent the seedling suffering from soil compactness and to make the plots weed free. Non-germinating setts were removed and sprouting setts from stock were replacement to achieve desire seedling in the plot. The critical period for crop-weed competition in sugarcane field to consider up to 140 DAP all the plots were kept weed free (Matin *et al*., 1998). Weeding was done twice just before at first and second top dressing of fertilizers. Flood irrigation was applied inside the trench after each top dressing (depending on soil moisture status). Earthing up was done around the base of each plant after 150 DAP.

3.1.3.12 Data collection

The data on healthy and infested cane per plot, number of total and infested internode per infested stem and number of *C. tumidicostalis* larva per infested stem were collected. Percent cane and internode infestation data were calculated.

3.1.3.12.1 Stem infestation

Cane infestation was calculated in percent using the following formula:

$$\text{Percent cane infestation} = \frac{\text{Number of infested canes}}{\text{Number of total canes}} \times 100$$

3.1.3.12.2 Internodes infestation

Total number of internodes and infested internodes was counted from randomly selected ten (10) infested canes in each individual plot. Internodes per cane infestation were calculated in percent using the following formula:

$$\text{Percent internodes per cane infestation} = \frac{A}{B} \times 100$$

A= Number of infested internodes per cane

B= Number of total internodes per cane

3.1.3.13 Data analysis and interpretation of results

The collected data on insect pests of sugarcane from different locations were analyzed using Microsoft Office MS Excel. After analysis results were interpreted with the aim to find out infestation intensity of *C. tumidicostalis*. Graphical interpretations were also performed wherever needed. The most vulnerable stage of plant growth for insect pests attack was also determined based on data.

3.2 Effeect of planting dates on the incidence and damage severity of sugarcane stem borer

3.2.1 Duration/Experimental period

The experiment was conducted during the period from September 2014 to December 2015.

3.2.2 Experimental site

The experimental site was located at the experimental farm of Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna, between 24.80^0 North latitude and 89.40^0 East longitudes with an elevation of 15.5 meter from the sea level (Anon, 2011).

3.2.3 Agro-ecological zone (AEZ)

The experimental field belongs to the active Ganges flood plain corresponding Agro-ecological zone (AEZ) 10 and is dark grey to brown flood plain soil (Figure 3.2.6).

3.2.4 Soil

3.2.4.1 Morphological characteristics

The soil of the experimental field was sandy loam in texture and slightly alkaline in nature with the $P^H$of around 7.65 and poor fertility status (Annual report, 2015) showing in Table 3.2.5.

Table 3.2.5 Morphological characteristics of soil in the experimental field 2014

Morphological features	Characteristics
Location	BSRI Experimental farm, Ishurdi, Pabna
AEZ	Active Ganges flood plain -10
General Soil Type	dark grey to brown floodplain soils
Land type	Highland
Topography	Plain land
Flood level	above normal flood level
Drainage	Well drained
Textural class	Sandy loam
Bulk density	1.65 g cm^{-3}
Particle density	2.69 g cm^{-3}

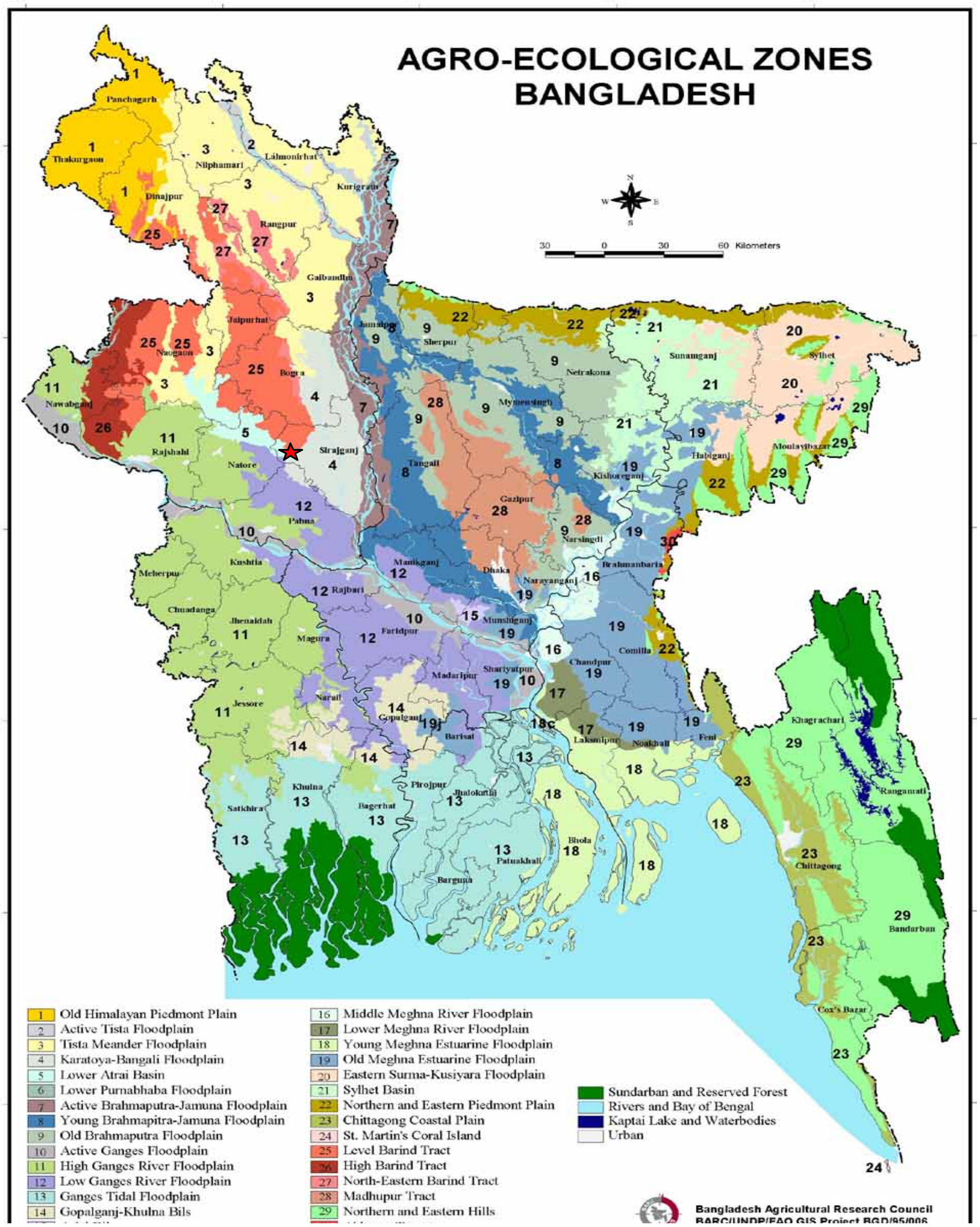


Figure 3.2.6. Map of Bangladesh showing the experimental field (★) in Agro-Ecological Zone (AEZ) during September 2014 to December 2015.

3.2.4.2 Analyses of soil chemical properties

3.2.4.2.1 Physico-chemical properties of the experimental soil

Before setting up of the experiment, soil samples were collected from the field of BSRI experimental farm which was used to fill the experimental pots. Physico-chemical properties of soil of experimental field was analyzed by BSRI in the Soil and Nutrition Laboratory, Ishurdi, Pabna (Annual report, 2015) and presented in Table 3.2.6.

Table 3.2.6 Physico-chemical properties of the experimental soil of BSRI experimental farm during 2014

Characteristics (0-15 cm soil depth)	Value	Methods employed
% Sand	42.84	Hydrometer method (Black, 1965)
% Silt	48.00	Do
%Clay	9.16	Do
Soil P^H	7.65	glass electrode P^H meter (Jackson, 1962)
Organic carbon (%)	0.60	Wet oxidation method (Page *et al.*,1982)
Organic matter (%)	1.03	Wet oxidation method Page *et al.*,1982
Total N (%)	0.06	Kjeldahl method (Bremner and Mulvaney, 1965)
Available P (ppm)	8.00	Olsen and Dean, 1965
Available Sulfer (ppm)	25.00	Calcium dihydrogen phosphate extraction (Hunter, 1984)
Exchangeable K (meq/100g)	0.26	N NH_4OAc extraction (Pratt, 1965)
Exchangeable Ca (meq/100g)	12.00	N NH_4OAc extraction
Exchangeable Mg (meq/100g)	0.89	N NH_4OAc extraction

3.2.5 Agro-meteorological feature

The climate of the experimental site is subtropical characterized by cold winter, hot and dry summer and heavy rainfall during the monsoon. During the experimental period heavy to moderate rainfall occurred from September-2014 and May-September, 2015. The highest rainfall (12.93 mm) was recorded in July, 2015. The temperature was higher during May-September, 2015 and decreased gradually from October in both years. The lowest temperature was found in December January 2014 (16.65 ^{o}C to 16.47 ^{o}C). The weather data recorded (monthes) and calculated average (maximum and minimum) air temperature (^{o}C), relative humidity (%) and rainfall for the crop-growing period (planting to harvest) from weather station of BSRI, Ishurdi, Pabna and presented in the Appendix 3.2.3.

3.2.6 Treatments

The experiment comprised of six (6) different planting dates as treatments. Each plantation was done in the middle of the months. The treatments were:

T_1= Planting on 15 September 2014
T_2= Planting on 15 October 2014
T_3= Planting on 15 November 2014
T_4= Planting on 15 December 2014
T_5= Planting on 15 January 2015
T_6= Planting on 15 February 2015

3.2.7 Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications in the field of the Entomology Experimental Farm, BSRI. The whole field (0.13 ha) was divided into four blocks consisted six (6) plots of equal size (6.0 m × 6.0 m) having two (2.0) m space between the blocks and one (1.0) m between the plots. Thus, the total number of plots was 24. Treatments were randomly assigned to each block as per design of the experiment (Figure 3.2.7).

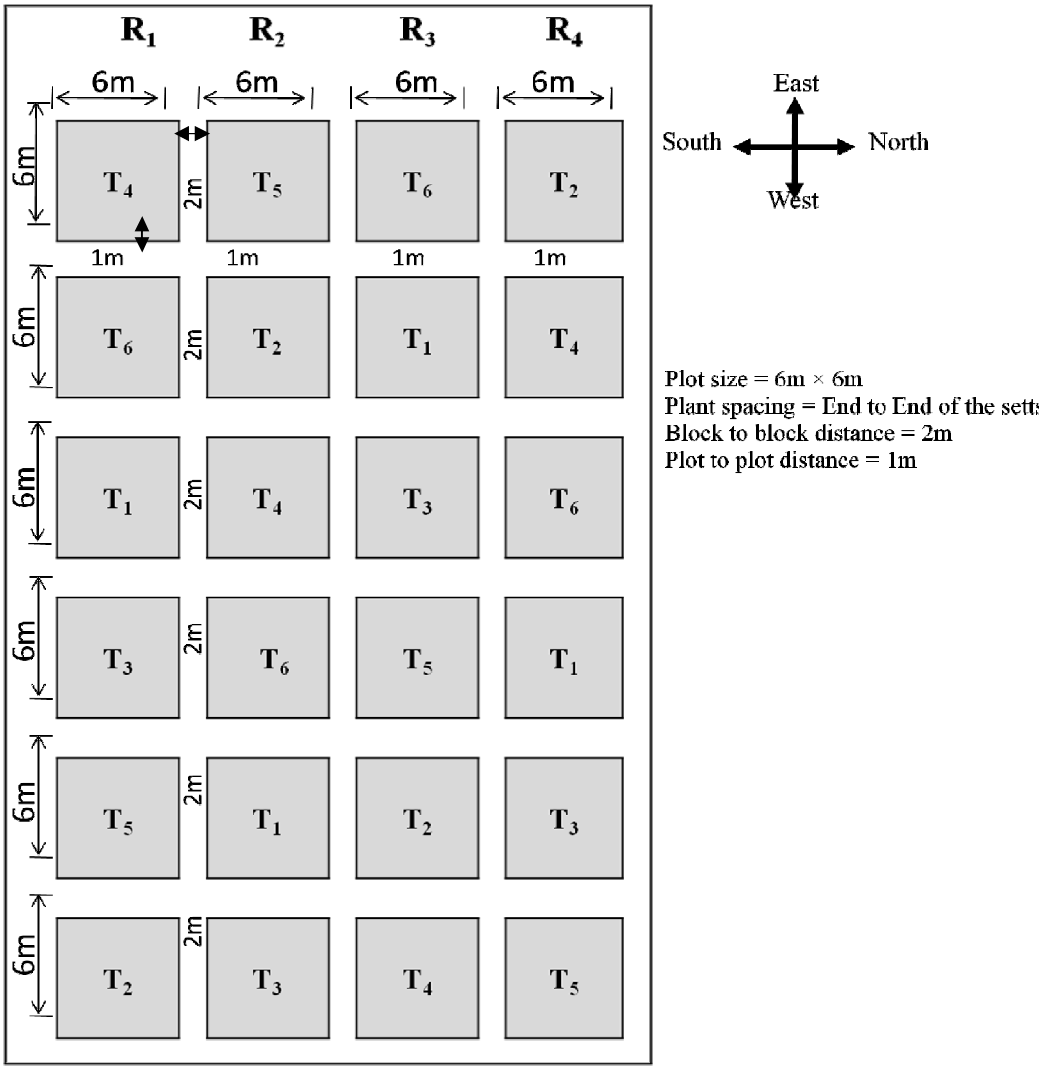


Figure 3.2.7 Field layout of the experiment with six treatments and four replications.

3.2.8 Land preparation

Soil of the experimental plot was prepared by three times ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth before 20 days of trench preparation. Weeds and other stubbles were removed carefully and finally prepared with the addition of basal dose of cow-dung in the experimental plots.

3.2.9 Trench preparation

Trench method was applied for sugarcane cultivation, and about 20.0 cm deep and 9.0 cm width trenches were made after the desired ploughing of soil maintaining a distance of 1.0 m between the rows. Soil at bottom of trench was loosened manually by spade (Figure 3.2.8 and Plate 3.2.1). Trench method was used to protect the crop from lodging.

A. Block wise plot separation   B. Trench preparation

Figure 3.2.8 Block separation and trench preparation for set placement in the experiment.

3.2.10 Manuring and fertilization

Manure and fertilizers were applied in the experimental field as per recommendation of BARC (2011). Doses of manure and fertilizers are presented in Table 3.2.7.

Table 3.2.7 Doses of manure and fertilizers used in experiment (BARC 2005)

Manures / Fertilizers	Doses / hectare	Amount required for
Cow-dung	10 tons	1.5 tons
Urea	358 kg	53.70 kg
Triple Super Phosphate (TSP)	275 kg	41.25 kg
Muriate of Potash (MP)	240 kg	36.00 kg
Gypsum	166 kg	24.90 kg
Zink Sulphate ($ZnSO_4$)	7 kg	1.05 kg

The full amount (1.5 ton) of cow-dung was applied as basal dose during land preparation. Fertilizers were used in different installments. Urea (53.70 kg) and MP (36.00 kg) were applied in three equal installments. Total amount of TSP (41.25 kg), Gypsum (24.90 kg), Zink Sulphate (1.05 kg) and one third of MP (12.00 kg) were applied in trenches and thoroughly mixed with soil prior to sett placing. First installment of urea (15.51 kg) was applied at the sett establishment stage. Two third quantity of MP (24.00 kg) and urea (35.80 kg) were applied as first and second top dressing at tiller completion stage (90 DAP) and grand growth phage (180 DAP). Top dressing of fertilizers was applied at root zone in furrows prepared on both sides of cane rows and then covered with soil.

3.2.11 Planting material

3.2.11.1 Sett collection

Setts of sugarcane variety Isd 37 was collected from Breeding Division, Bangladesh Sugarcrop Research Institute (BSRI). The variety was released in 2006 from BSRI, Ishurdi, Pabna and its parentage was Cok 31 × CP 50-72 [(CoK= Coimbatore-Karnal (India) and CP = Canal Point (Florida)].

3.2.11.2 Sett preparation

Healthy, vigor, pest and disease free cane was selected from the upper two third portion of the stem. Then the cane was cut as such that each sett contained two buds. Rooted setts and damaged buds were separated from healthy setts.

3.2.11.3 Sett treatment

The setts were dip in Bavistin solution (1:1000) for 30 minutes to control the sett and soil born fungal disease (Talukder *et al.*, 2005).

3.2.11.4 Sett placement

Two budded pre-germinated setts were planted end to end in trenches in the main field (Figure 3.2.9). Planting was done through conventional sett placement in the trenches (Matin *et al*., 1989).

A. Setts treatment **B. Setts placement**

Figure 3.2.9. Setts treated with advestin and placement in the trench.

3.2.12 Intercultural operation

Intercultural operations such as gap filling, irrigation, weeding, mulching, earthing-up and tying were appropriately done throughout the cropping season to facilitate proper growth and development of canes (Rahman and Pal, 2003). Light irrigation was given at 7 days interval for porper germination of sett. Crust of surface soil inside the trenches was broken twice at 30 and 60 days after set placement for loosening the soil and to prevent the seedling suffering from soil compactness and to make the plots weed free. Non-germinating setts were removed and sprouting setts from the stock were replaced to achieve desire seedling in the plot. The critical period for crop-weed competition in sugarcane field to consider up to 140 DAP all the plots were kept weed free (Matin *et al*., 1998). Weeding was done twice just before at first and second top dressing of fertilizers. Flood irrigation was applied inside the trench after each top dressing (depending on soil moisture status). Earthing up was done around the base of each plant after 150 DAP.

3.2.13 Data collection

The effect of different treatments in controlling and reducing sugarcane stem borer infestation was evaluated on the basis of infestation of stem and internodes and subsequent yield per hectare.

3.2.13.1 Infestation

3.2.13.1.1 Cane infestation

The total number of canes as well as the number of infested canes was recorded from each individual plot at monthly intervals. Percent cane infestation was calculated using the following formula:

$$\text{Percent cane infestation} = \frac{\text{Number of infested canes}}{\text{Number of total canes}} \text{ x } 100$$

3.2.13.1.2 Internodes infestation

Total number of internodes and infested internodes was counted from randomly selected ten (10) infested canes in each individual plot at monthly intervals. Percent internodes infestation per cane was calculated using the following formula:

$$\text{Percent internodes per cane infestation} = \frac{A}{B} \times 100$$

A= Number of infested internodes per cane.

B= Number of total internodes per cane.

Plate 3.2.1. Trench preparation for plantation at different dates

Plate 3.2.2. Early stage at different planting dates

Plate 3.2.3. Middle stage at different planting dates

Plate 3.2.4. Vegetative growth stage in the month of May

Plate 3.2.5. Newly infested cane with penetrating hole and freshes

Plate 3.2.6. Severly damaged and larva inside cane when longitudinal cut.

3.2.13.2 Number of larva

Stem borer infested cane was selected in each individual treated plot. The infested stem was cut longitudinally and counted the number of stem borer larva.

3.2.14 Yield

Canes were harvested when maturity occurred (12 months DAP) which was determined by measuring Brix (%) in cane with the help of hand refractometer following the standard field procedure recommended by BSRI (Chen, 1985; Jabber *et al.*, 2005).The weight of healthy, infested and total canes was noted separately per individual plot for each treatment. The yield of cane was expressed in ton ha^{-1}. Percent increase or decrease yield of cane in different treatments over untreated control was calculated by using the following equations:

$$\text{Percent increased yield (weight)} = \frac{A - B}{A} \times 100$$

A=Weight of cane in treated plot

B=Weight of cane in untreated plot

The cumulative plot yield of healthy and infested canes were transformed into healthy, infested and total yield per hectare in tons, respectively.

3.2.15 Statistical analysis

All the collected data were subjected to proper statistical analysis. The percentage data was subjected to ArcSin transformation while the data in number was subjected to square root transformation as and when needed.The data was analyzed by using MSTAT-C statistical package programme. Analysis of variance (ANOVA) was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Graphical interpretations were also performed wherever needed.

3.3 Screening of some sugarcane varieties against sugarcane stem borer *(Chilo tumidicostalis)* in Bangadesh

3.3.1 Experimental period

The experiment was conducted during the period from November 2014 to December 2015.

3.3.2 Experimental site

The experimental site was located at the farmer's field at Natore Sugar Mills Zone area about 24.41^0 North latitude and 88.93^0 East longitudes with an elevation of 15.5 meter from the sea level (Anon., 2011).

3.3.3 Agro-Ecological Zone (AEZ)

The experimental field belonged to the High Ganges flood plain corresponding Agro Ecological Zone (AEZ) No. 11 and was dark grey to brown flood plain soil (Figure 3.3.10).

3.3.4 Soil

The soil of the experimental field was medium high with sandy loam in texture and slightly alkaline in nature. Its PH of around 7.68 with poor fertility status and dark grey to brown flood plain soil type.

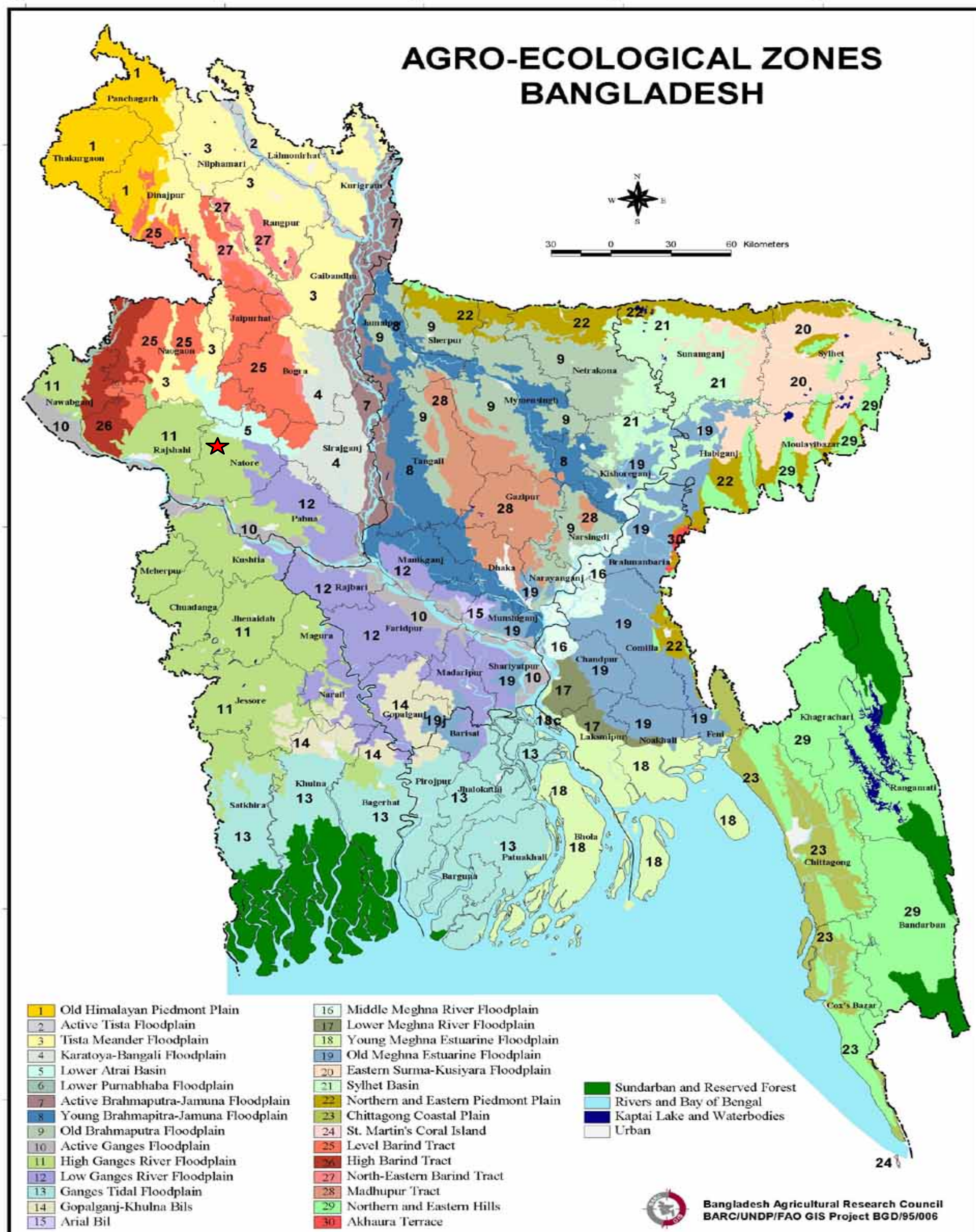


Figure 3.3.10. Map of Bangladesh showing the experimental field (★) in Agro Ecological Zone (AEZ) 11 at Natore district.

3.3.5 Weather/Climate

The experimental site was situated in the subtropical climatic zone, characterized by heavy rainfall during the month of May to September and scanty rainfall during the rest of year. The weather data recorded monthly and calculated average (maximum and minimum) air temperature (^{o}C), relative humidity (%) and rainfall as monthly during the crop-growing period (planting to harvest) from weather station of BSRI, Ishurdi, Pabna and presented in Appendix 3.3.4.

3.3.6 Treatments

The experiment comprised ten (10) intensive cultivated commercial sugarcane varieties as treatments at sugar mills zone of Bangladesh. The parentage of 10 varieties and released year are shown in Table 3.3.8.

Table 3.3.8. Parentage of ten tested varietes and released year

Name of sugarcane varieties	Parentage	Year of release
Isd 16	CP 36-13 × Bo 32	1981
Isd 20	Co 1148 × Misri Lal	1990
Isd 26	Isd 16	1995
Isd 33	Co 631 × 1144-86	2002
Isd 34	Introduced from India	2002
Isd 36	CP 70-1133 × ? (Polycross in other variety)	2003
Isd 37	Cok 31 × CP 50-72	2006
Isd 38	1273-91 × Isd 28	2007
Isd 39	BC_5× Isd 25	2009
Isd 40	Isd 27 × Isd 24	2009

Isd= Ishurdi, I = Ishurdi (Bangladesh), Co= Coimbatore (India), 1970 release No. 10., CoK= Coimbatore (Fuzz)- Karnal (India), selection 30, CP= Canal Point (Florida), 1965, selection 357, BC= Back Cross

3.3.7 Design and Layout

3.3.7.1 Design of Experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Experimental Farm, BSRI.

3.3.7.2 Layout of Experiment

The whole field (1376 m^2) was divided into three blocks and each block consisted of 10 plots of equal size (9.0 m x 9.0 m) having 2 m space between the blocks and 1.0 m between the plots. Thus, the total numbers of plot were 30. Different combinations of treatments were assigned to each plot as per design of the experiment (Appendix 3.3.5).

3.3.8 Land preparation

Ploughing, trench preparation, manuring and fertilization were same as described in Experiment 2.

3.3.9 Sett collection, prepartation, treatement and plantation

Ten (10) sugarcane varieties were collected from experimental farm at Natore Sugar Mills Limited. All theses varieties were commercially released from BSRI, Ishurdi, Pabna. Sett preparation, sett treatment and sett placement were same as described Experiment 2.

3.3.10 Intercultural operations

Intercultural operations such as weeding, mulching, earthing up etc. were same as described in Experiment 2.

Plate 3.3.7 Lebeling of the experimental plot.

Plate 3.3.8 Dead heart caused by *C. tumidicostalis*.

Plate 3.3.9 Root initiation and lateral shoot germimation on stem caused by *C. tumidicostalis*.

Plate 3.3.10. Infested stem showing penitration hole caused by *C. tumidicostalis.*

Plate 3.3.11. Dry out after death of sugarcane plant caused by *C. tumidicostalis*.

3.3.11 Data collection

The performance of 10 sugarcane varieties against *C. tumidicostalis* was assessed on the basis of stem and internodes infestation and subsequent yield per hectare. Data on biophysical and biochemical characteristics of these different varieties were collected separately and relationship of these characteristics with *C. tumidicostalis* infestation was assessed.

3.3.11.1 Stem and internode infestation

Data collection procedures on cane/stem infestation, internode infestation symptoms and number of larva were described in Experiment 2.

3.3.12 Biophysical characteristics of ten sugarcane varieties

Data on observable morphological characters of 10 sugarcane varieties were recorded on August when heavy infestation occurred. Morphological characteristics were selected based on the previous information reported by several researchers (Shahi 2000; Moore, 1987; Artschwager and Brandes, 1958). Morphological features including leaf and stem characteristics of the 10 sugarcane varieties were observed.

3.3.12.1 Leaf characteristics

Leaf characteristics of ten cultivated sugarcane varieties including length of leaf sheath and leaf blade. For data collection on biophysical characteristics of leaves, ten plants were selected randomly from each plot under each variety in August 2015 when heavy infestation of *C. tumidicostalis* occurred. Length of the leaf sheath and leaf blade of each variety was measured and recorded separately.

3.3.12.2 Stem characteristics

Stem characteristics of ten cultivated sugarcane varieties including stem colour, pith in the interior of stem and fiber content were observed and recorded. For data collection on biophysical characteristics of stem, five plants were selected randomly from each plot under each variety on August 2015 when heavy infestation of *C. tumidicostalis* occurred. Stem color was observed visually and recorded as per description of BSR (2010) for these varieties. For estimation of pith inside the stem, cross section ofstem was done and presence of pith in the interior of stem was observed visually on eye estimation and recorded separately for each variety (Figure 3.3.11).

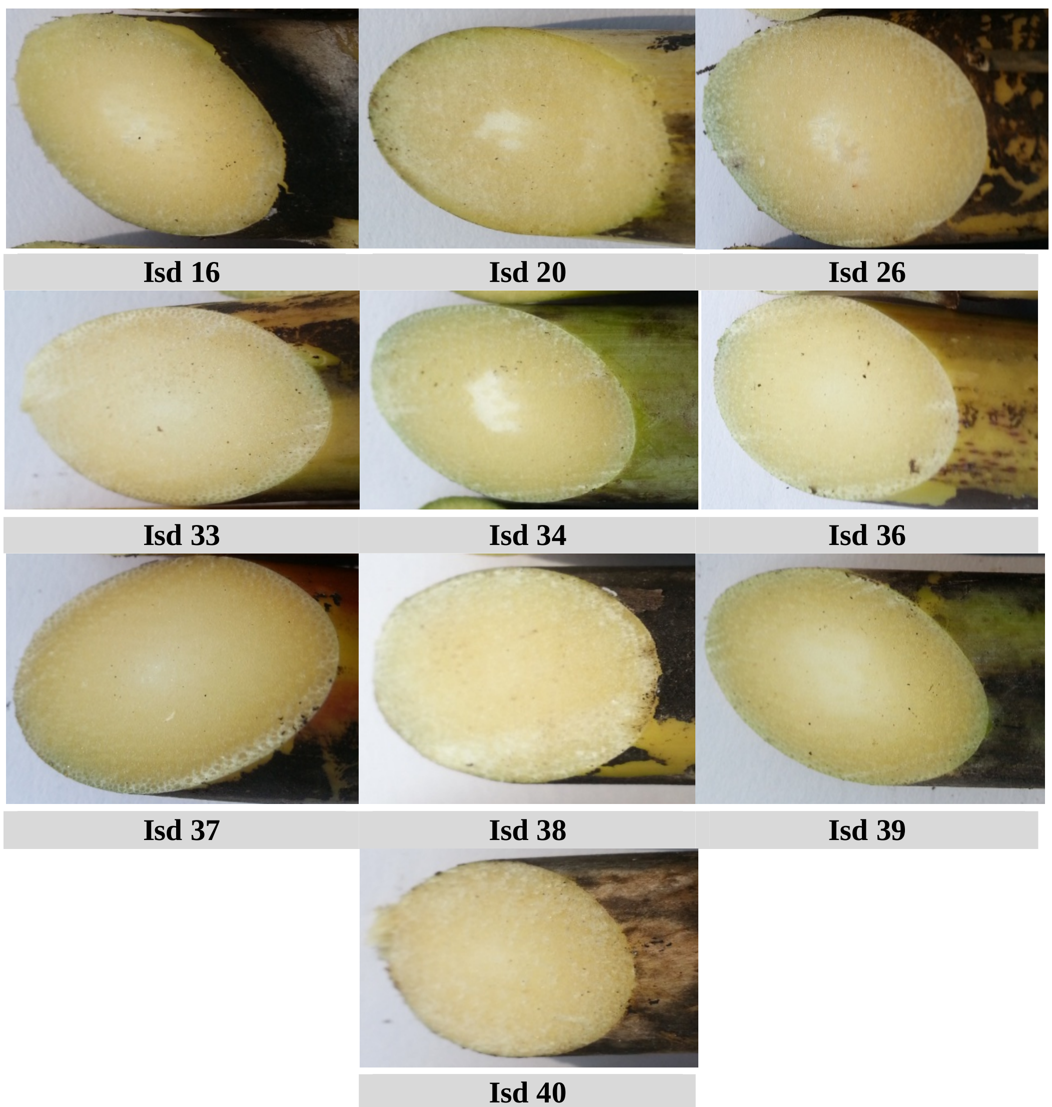


Figure 3.3.11. Cross section of the stems of 10 sugarcane varieties showing presence or absence of pith.

3.3.12.3 Fiber content of stem

Fiber content was determined by Prepared Cane Method (Anderson and Petersen, 1959) at Chemistry Laboratory of BSRI. For this, fresh cane was grinded by grinding machine. Then 100 g sample from each variety was rapidly transferred in a cloth bag. The bag was weighed in an air-tight container before taking the sample which was considered as W_1. Then weight of the cloth bag including 100 g sample was taken and recorded as W_2. The bag with sugarcane sample was washed in running tap water for 15 minutes to remove the liquid part from sugarcane sample. After that, the bag was immersed in boiling water, repeating the procedure for another hour and squeezed at the commencement of washing and at 15 minutes interval for a period of one hour. Surplus water was removed from the sample by squeezing or spin drying and transferred to an air oven. The sample was dried at 100 to 105 ^oC for constant weight. After removal from the oven for weighing, the bags were placed in the airtight container. The weight of the container + bag + fibre (W_3) was recorded. Fibre was remomed from the bags and dried in the oven for one hour at 100 to 105 ^oC. Airtight container and bags (dried) were recorded as (W_4).

$$\text{Percent fibre in cane} = \frac{W_3 - W_4}{W_2 - W_1} \times 100$$

W_1= weight of bag + container (predried)

W_2= Weight the bag + container + fibre (predried)

W_3 = weight of container + bag + fibre (dried)

W_4 = weight of container + bag (dried)

3.3.13 Biochemical analysis of 10 sugarcane varieties

Biochemical analysis of 10 sugarcane varities were done at laboratory of BSRI, Soil Resources Development Institute (SRDI) and Bangladesh Council of Scientific and

Industrial Research (BCSIR). Brix percentage, pol percent cane and reducing sugar were determined at BSRI laboratory; nitrogen, phosphorus and potassium were estimated at (SRDI) laboratory and silicon estimation was done at BSCIR laboratory following the standard methods.

3.3.13.1 Estmiation fof brix percentage

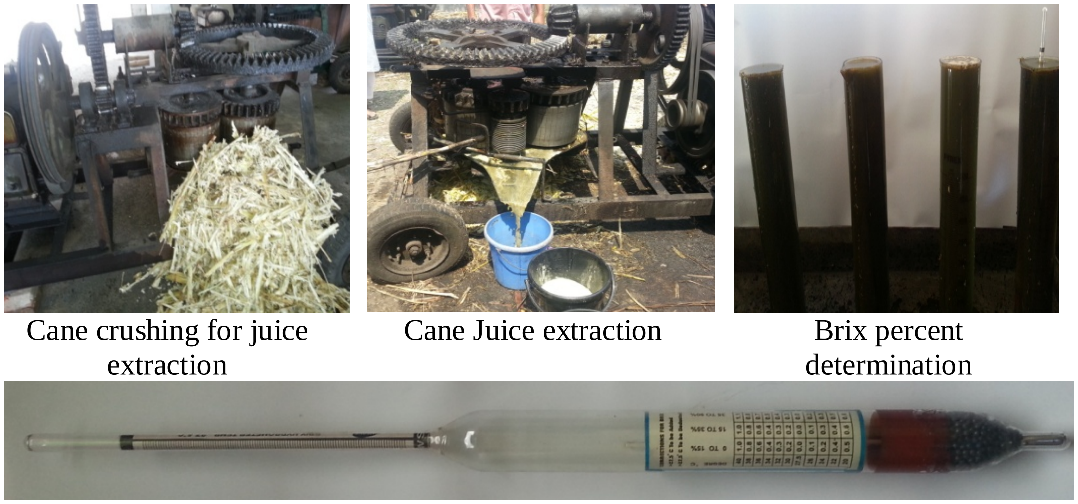
Brix is actually a measurement of the percent of soluble solids in the sugarcane juice or percentage by weight of sucrose in pure water solution. This designation of Brix degrees is only valid for pure sucrose solutions. Pure sucrose is extracted from sugarcane juice and quality was estimated through brix percentage. Higher brix reading indicates higher sucrose content. The brix percentage from infested canes of ten varieties was measured at BSRI laboratory by the Brix Hydrometer.

3.3.13.1.1 Sample preparation

Three infested canes from each plot were selected randomly. Juice extraction was done by electric crushing machine at Physiology and Sugar Chemistry Laboratory, BSRI, Ishurdi, Pabna. The juice was first thoroughly mixed and strained through a fine mesh to remove the particles of bagasse, wax and other suspended impurities (Figure 3.2.12).

3.3.13.1.2 Procedure of brix percent determination

The meter was zeroed using Milli Q water prior to obtaining a Brix measurement for each sugar solution. A wide cylinder was filled to the brim with the sample of juice and set it aside for few minutes for the escape of air bubbles. The Hydrometer was then lowered into the cylinder for escaping the bubbles causing the juice overflow that carry away with it the forth and impurities floating up on the surface. The Hydrometer lowered further into the juice until it floats. After allowing sufficient time for the temperature of the Hydrometer to reach to that of juice, the reading of the Hydrometer was noted just near the lower meniscus. The temperature of the juice was noted simultaneously and the corrected brix was found out from the temperature correction table.



Cane crushing for juice extraction | Cane Juice extraction | Brix percent determination

Brix Hydrometer

Figure 3.3.12. Cane grinding for juice extraction, brix percentage determination process.

3.3.13.2. Estimation of pol percent juice

3.3.13.2.1 Clarification of juice

Horne's Dry Lead Sub-Acetate was used to clarify cane juice and 200 ml juice was taken in a reagent bottle and 2-3 g of Horne's Dry Lead Sub-Acetate was added. The content of the reagent bottle was then shaken vigorously for about a minute and then filtered. The clear filtrate was then ready for pol determination.

3.3.13.2.2 Determination of pol (%) juice

Pol percent juice was measured by using automatic polarimeter (model AP-300, Atago Co., Ltd, Japan). The clear juice was filled in a 200 mm polarimeter tube. Care was taken not to present any air bubbles inside the tube after filling with clarified juice. The polarimeter/saccharimeter was adjusted and focused distinctly as the position of the image was changed. Correct adjustment was found both halves of the field of view appear in equal brightness and the direct pol was obtained from the scale. The pol was corrected against brix from the correction table (Reference: Schmitiz's Table for sucrose (pol) for use in Horne's Dry Lead method with undiluted solution).

Juice purification — purified juice

Pol percent cane determination — Reducing sugar determination

Figure 3.3.13. Juice purification, pol percent juice and reducing sugar estimation process.

3.3.13.3 Estimation of reducing sugar

Reducing sugar from juice of 10 varieties were estimated by Lane and Eynon Method. Fehling's solution was prepared just prior to the titration by pipetting 5 ml of Fehling's A solution and 5 ml of Fehling's B solution into a 250 ml boiling flask.

3.3.13.3.1 Exploratory titration

Approximately 15 ml of the test solution was added from an offset burette to the prepared Fehling's solution and was boiled by heat. The color of the boiling solution was given an indication of the additional quantity of test liquid required reducing the remaining copper. The end point was appeared and then boiling was done for two minutes after addition of four drops of methylene blue indicator. The titration in aliquots of 1 ml or less until the color was completely discharged.

3.3.13.3.2 Final Titration

The rough titration less than approximately 0.5 ml was added with ten (10) ml of mixed Fehling's solution and then boiling was done by heat for two mimutes. Four drops of methylene blue indicator was added and recommence the titration after 15 seconds. The titration was completed within three minutes (Figure 3.3.13).

3.3.13.3.3 Calculation of results

The reducing power of an invert sugar solution is affected by both the volume of the final solution and the concentration of sucrose present in the solution.

3.3.13.4 Estimation of nitrogen, phosphorus, potassium and silicon

3.3.13.4.1 Sample preparation for nitrogen, phosphorus, potassium and silicon analysis

Sample of ten sugarcane varieties was prepared at Agricultural Chemistry Laboratory of Sher-e-Bangla Agricultural University. The specimens of sugarcane stems were cut into small pieces and crushed by crushing machine. Crushed samples were dried in an oven at 65-70^{o}C for 72 hours. After drying the samples were grinded by a grinding machine to pass through a 20 mesh sieve and stored in air tight poly bag and kept into desiccators for chemical analysis.

3.3.13.4.2 Determination of nutrient elements

Nutrient elements such as nitrogen, phosphorus and potassium were estimated according to Yamakawa (1992) by using Micro Kjeldahl, Spectrophotometric Molybdovanadate and Flame Photometric Methods respectively. These analyses were done at Soil Resource and Development Institute (SRDI), Farmgate, Dhaka.

3.3.13.4.2.1 Nitrogen (N)

3.3.13.4.2.1.1 Digestion of samples with sulphuric acid

An amount of 100 mg oven dry ground sample was taken in a 100 ml Kjeldahl flask and 1.1 g catalyst mixture (K_2SO_4:$CuSO_4$ 5 H_2O: selenium in the ratio 10:1:0.1), 2 ml 30% H_2O_2 and 3 ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes. After that, the flask was heated and continued until the digest became clear and colorless. After cooling, the digest was transferred into 100 ml volumetric flaks and the volume was made up to the mark with distilled water. A reagent blank was prepared in similar way. This digest was used for the estimation of total N.

3.3.13.4.2.1.2 Determination of total N

N contents in the digest were determined following the Micro-Kjeldahl method as described in case of stem analyses and N in the digest was determined by distillation with 40% NaOH followed by titration of distillate trapped in H_2BO_3 (4%) with 0.02 N H_2SO_4 (Jackson ,1973).

3.3.13.4.2.2 Phosphorus

P concentration in the stem samples was determined after digestion with HNO_3 and $HClO_4$ mixture in 5:2 ratios. Phosphorus was determined from the digest by adding ammonium molybdate and ammonium vanadate solution and measuring the color with the help of a spectrophotometer at 660 nm wavelength.

3.3.13.4.2.3 Potassium

K content in leaf samples was determined directly with the help of flame photometer after digesting the samples with di-acid mixture (Figure 3.3.14).

3.3.13.4.2.4 Determination of silicon

Silicon contains in sugarcane stems of different sugarcane varieties were analyzed at Bangladesh Council of Scientific and Industrial Research (BSCIR) laboratories, Dhaka. Grinding samples were prepared in Microwave Digestion System and analyzed by High Temperature Atomic Absorption Spectrometric Method.

Nitrogen digesion (Heating digester, DK, VELP Scientifica)

N Distilation
(VELP Scientifica)

Potassium determination
PFP7 Flame Photometer
(Jenway)

Phosphorus determination
UV-1800 UV
Spectrophotometer
(Company- Shimadzu)

Figure 3.3.14. Nitrogen, potassium and phosphorus determination by using these instruments**.**

3.3. 14 Yield

Canes were harvested at maturity (12 months DAP) which was determined by measuring Brix (%) in cane with the help of hand refractometer following the standard field procedure recommended by BSRI (Chen, 1985, Jabber *et al.*, 2005). The weight of healthy, infested and total canes was noted separately per individual plot for each treatment. The yield of cane was expressed in ton ha^{-1}. Percent increase or decrease yield of cane in different treatments over untreated control was calculated by using the following equations:

$$\text{Percent increased yield (weight)} = \frac{A - B}{A} \times 100$$

A= Weight of cane in treated plot

B= Weight of cane in untreated plot
The cumulative plot yield of healthy and infested canes were transformed into healthy, infested and total yield per hectare in tons respectively.

3.3.15 Statistical analysis

All the collected data were subjected to proper statistical analysis. The percentage data was subjected to ArcSin transformation while the data in number was subjected to square root transformation as and when needed. The data was analyzed by using MSTAT-C statistical package programme. Analysis of variance (ANOVA) was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Graphical interpretations were also performed wherever needed.

3.4 Evaluation of some chemical insecticides against sugarcane stem borer in field

3.4.1 Experimental period

The experiment was conducted during the period from November 2013 to December 2014.

3.4.2 Experimental site

The experiment was conducted at Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna. Details about experimental site have been described as Experiment 2.

3.4.3 Soil

Morphological characteristics, chemical properties and physicochemical properties of the soil in experimental field have been described in Experiment 2.

3.4.4 Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications in the field. The whole field (0.13 ha) was divided into four blocks consisted six (6) plots of equal size (6.0 m × 6.0 m) having 2.0 m space between the blocks and 1.0m between the plots. Thus, the total number of plots was 24. Treatments were randomly assigned to each block as per design of the experiment (Figure 3.4.15).

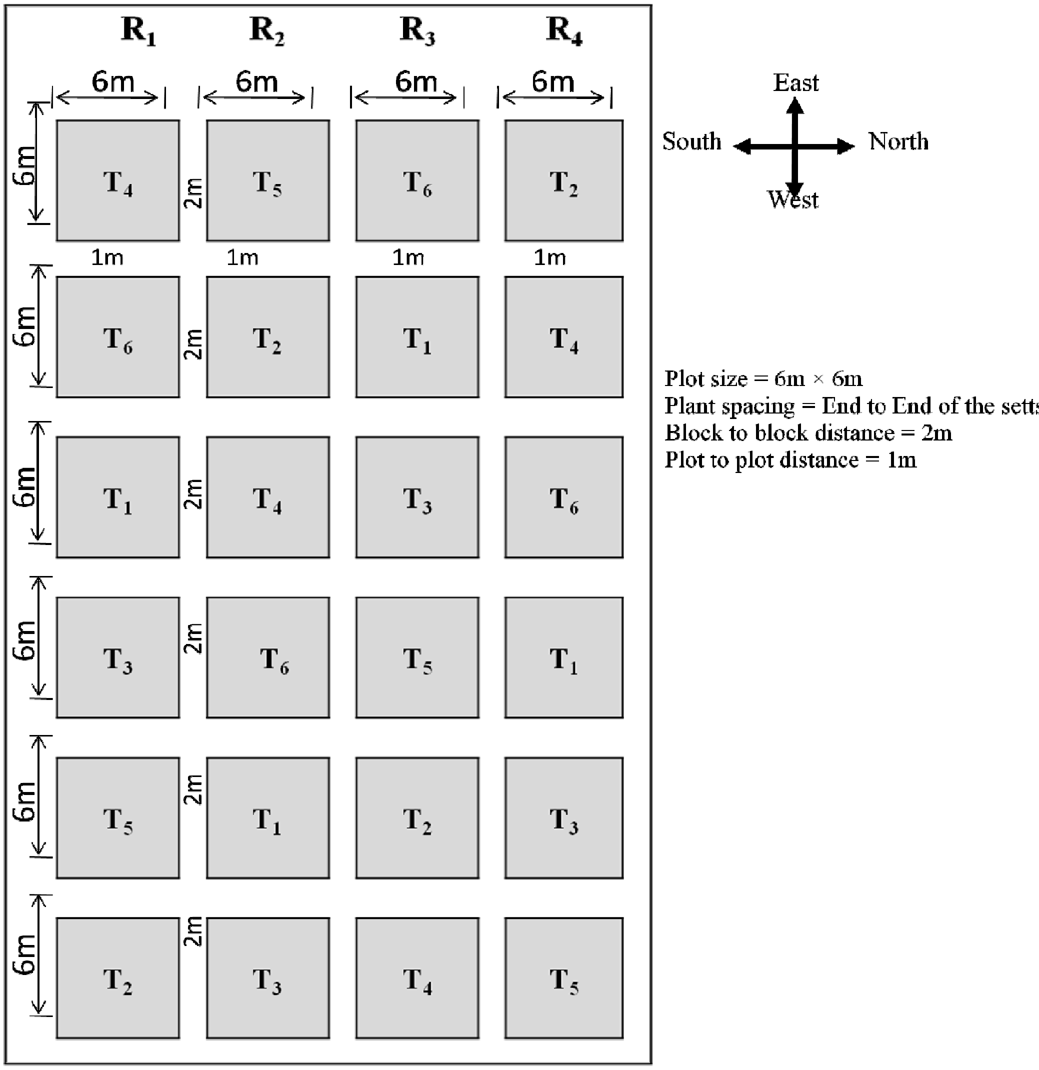


Figure 3.4.15. Layout of the experiment with six treatments and four replications.

3.4.5 Treatments

The experiment comprised 6 (six) treatments such as T_1= Care 4G@ 75.0 kg ha^{-1}, T_2= Carbofuran 5G @ 40.0 kg ha^{-1}, T_3= Virtaco 40WG @ 300.0 g ha^{-1}, T_4= Cidan 4G @ 75.0 kg ha^{-1}, T_5 = Nokotap 6G @ 50.0 kg ha^{-1}, and T_6= no insecticides (untreated (control). Treatments were applied 3 times at one month interval starting from June when infestation was observed.

3.4.6 Application of insecticides

Only Virtaco 40WG was water soluble and applied as topical spray by knapsack sprayer. Other four insecticides were granular in formulation and applied by broadcasting method in furrows between rows.

3.4.6.1 Spray

Water soluble insecticide (Virtaco 40WG) was applied with the help of Knapsack sprayer. Virtaco 40WG was mixed with water at the rate of 0.6 g per liter of water. About 3.6 liters of spray volume was required to spray each individual plot per spraying. Spray was applied on upper and lower surfaces of the leaves and stem to ensure complete coverage of the plants. The spray was always done early in the morning to avoid scorching sunshine, strong wind, insecticidal drift and to save beneficial insects. During the application of insecticides, precautions were taken to avoid drift to adjacent plots.

3.4.6.2 Soil application of granular insecticides

Granular insecticides were applied in furrows between rows of sugarcane. Furrow was done in each row near the base of the plant. After application of granular insecticides, the furrow was closed with soil. A light irrigation was applied before five days of insecticides application in furrows to ensure sufficient moisture in the soil.

3.4.7 Soil and trench preparation

Soil and trench preparation procedures were same as described in Experiment 2.

3.4.8 Manuring and fertilization

Doses of manures and fertilizers and application procedures were the same as described for Experiment 2.

3.4.9 Sett

3.4.9.1 Sett collection, preparation, treatment, placement and intercultural operation

Setts of sugarcane variety Isd 37 was collected from Breeding Division, Bangladesh Sugarcrop Research Institute (BSRI). The variety was released in 2006 from BSRI, Ishurdi, Pabna and its parentage was Cok 31 x CP 50-72 [(CoK= Coimbatore-Karnal (India) and CP = Canal Point (Florida)]. Sett preparation, treatment, placement and intercultural operations are discribed as experiment 2.

3.4.10 Data collection

The effect of different treatments in controlling and reducing sugarcane stem borer infestation was evaluated on the basis of infestation of stem and internodes and subsequent yield per hectare.

3.4.10.1 Infestation

3.4.10.1.1 Cane infestation

The total number of canes as well as the number of infested canes was recorded from each individual plot at monthly intervals. Cane infestation was calculated in percent using the following formula:

$$\text{Percent cane infestation} = \frac{\text{Number of infested canes}}{\text{Number of total canes}} \times 100$$

3.4.10.1.2 Internodes infestation

Total number of internodes and infested internodes was counted from randomly selected ten (10) infested canes in each individual plot at monthly interval. Internodes per cane infestation were calculated in percent using the following formula:

$$\text{Percent internodes per cane infestation} = \frac{A}{B} \times 100$$

A= Number of infested internodes per cane

B= Number of total internodes per cane

3.4.10.1.3 Number of larva

One stem borer infested cane (Plate 3.4.15) was selected in each individual treated plot. The infested stem was cut longitudinally and number of stem borer larva was counted.

Plate 3.4.12 Infested cane showing root initiation and lateral shoot germination by *C. tumidicostalis*

Plate 3.4.13 Infested cane showing freshes and lateral shoot germination by *C. tumidicostalis*

Plate 3.4.14 Infested cane showing larva of *C. tumidicostalis*inside stem.

Plate 3.4.15 Larva of *C. tumidicostalis.*

3.4.11 Yield

Canes were harvested at maturity (12 months DAP) which was determined by measuring the brix percentage in cane with the help of hand refractometer following the standard field procedure recommended by BSRI (Chen, 1985; Jabber *et al*., 2005). Weight of healthy, infested and total canes was noted separately per individual plot for each treatment. The yield of cane was expressed in ton ha^{-1}. Percent increase or decrease of cane yield in different treatments over untreated control was calculated by using the following equations:

$$\text{Percent increased yield (weight)} = \frac{A - B}{B} \times 100$$

A=Weight of cane in treated plot

B=Weight of cane in untreated plot

The cumulative plot yield of healthy and infested canes was transformed into healthy, infested and total yield per hectare in tons seperately.

3.4.12 Statistical analysis

All the collected data were subjected to proper statistical analysis. The percentage data was subjected to ArcSin transformation while the data in number was subjected to square root transformation as and when needed. The data was analyzed by using MSTAT-C statistical package programme. Analysis of variance (ANOVA) was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Graphical interpretations were also performed wherever needed.

3.5 Development of integrated management practices against sugarcane stem borer

3.5.1 Description of the experimental site

3.5.1.1 Experimental period

The experiment was conducted during the period from November 2015 to December 2016.

3.5.1.2 Experimental site

The experimental site was located at the farmer's field at Joypurhat Sugar Mills Zone area about 25.10^0 North latitude and 89.03^0 East longitudes with an elevation of 15.5 meter from the sea level (Anon, 2011).

3.5.1.3 Agro-ecological Zone (AEZ)

The experimental field belongs to the Tista Meander Flood plain corresponding Agro Ecological zone (AEZ) No. 3 and is grey or dark grey flood plain soil (Figure 3.5.16).

3.5.1.4 Soil

The soil of the experimental field was heavy silt loam in texture and moderately acidic in nature. Its P^H was around 6.16 with poor fertility status and has good moisture holding capacity.

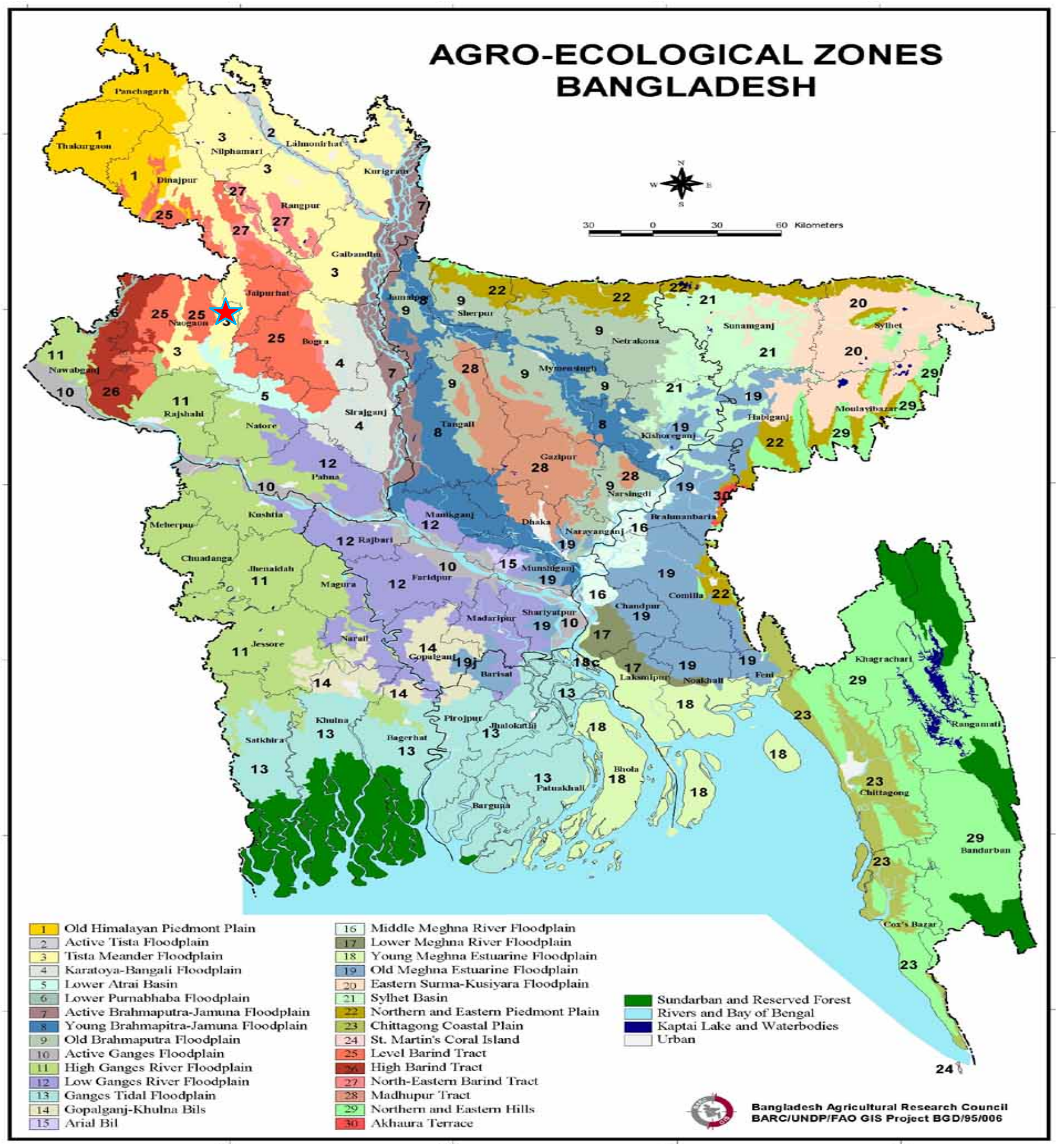


Figure 3.5.16. Map of Bangladesh showing the experimental site (★) in Agro-Ecological Zone (AEZ) No. 3.

3.5.2 Design and Layout

3.5.2.1 Design of Experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in the field of the farmer's field at Joypurhat Sugar Mills Zone.

3.5.2.2 Layout of Experiment

The whole field (0.27 ha) was divided into three blocks and each block consisted of 9 plots of equal size (9.0 m x 9.0 m) having 2.0 m space between the blocks and 1.0 m between the plots. Thus, the total number of plot was 27 and treatments were assigned randomly in each block as per design of the experiment (Figure 3.5.17).

3.5.3 Treatments

The experiment comprised nine combinations of different components including check varity and each combination was considered as an IPM package. The treatments were as follows:

T_1= Sugarcane variety Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane three times in mid July, August and September

T_2= Sugarcane variety Isd 36 + Planting on 15 November + De-trashing (removal of dead leaves three times in mid July, August and September)

T_3= Sugarcane variety Isd 36 + Planting on 15November + Nokotap 6G @ 50 kg ha^{-1} three times

T_4= Sugarcane variety Isd 36 + Planting on 15 November + Hand cutting + De-trashing (removal of dead leaves three times in mid July, August and September)

T_5= Sugarcane variety Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1} (Cartap)

T_6= Sugarcane variety Isd 36 + Planting on 15 November + De-trashing (removal of dead leaves three times in mid July, August and September)+ Nokotap 6G @ 50 kg ha^{-1} (Cartap)

T_7= Sugarcane variety Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane+ De-trashing (three times in mid July, August and September) + Nokotap 6G @ 50 kg ha^{-1}(Cartap)

T_8= Sugarcane variety Isd 36 + Planting on 15 November

T_9= Sugarcane variety Isd 40 + Planting on 15 November

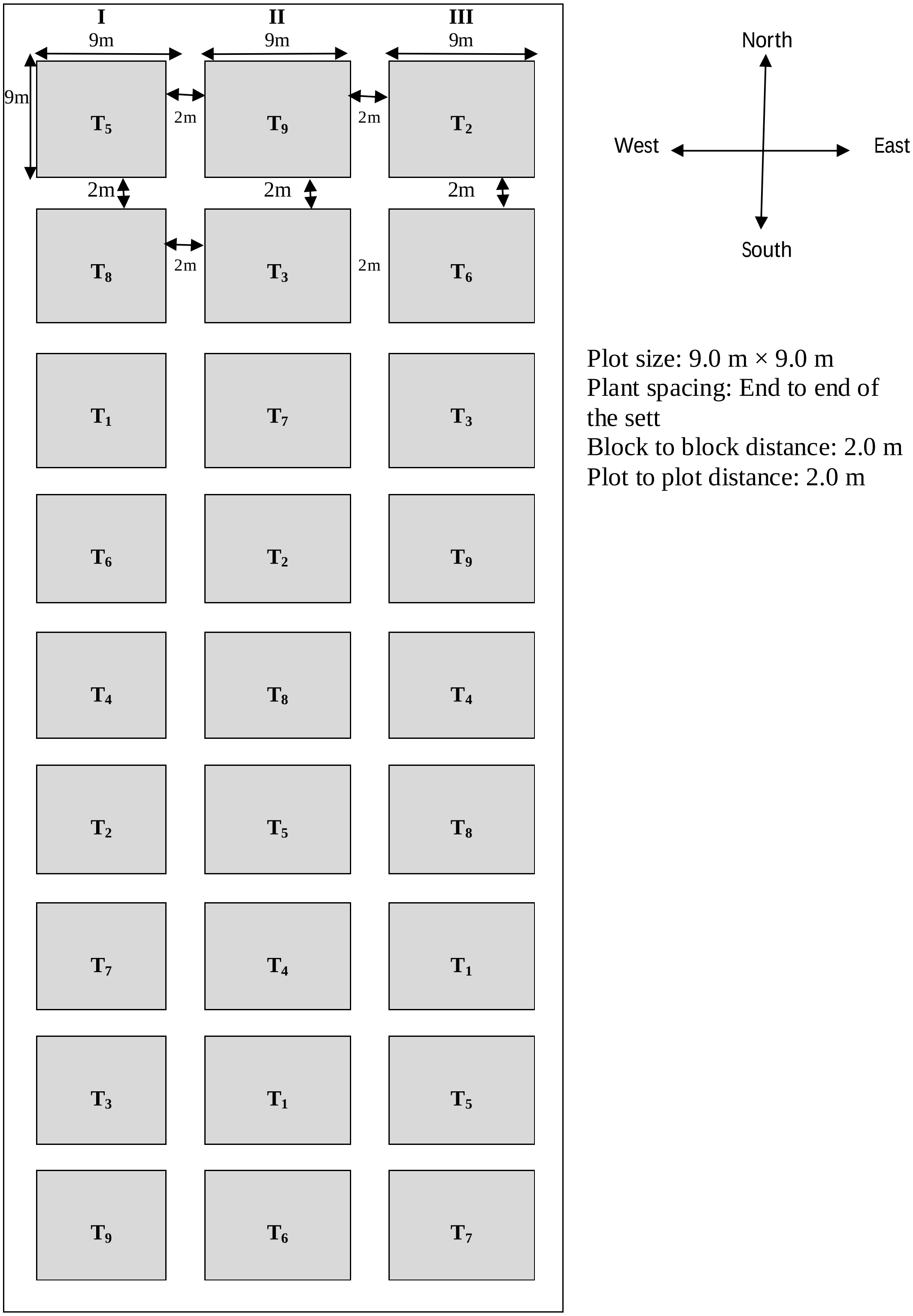


Figure 3.5.17. Layout of the experiment with nine treatments and three replications.

3.5.4 Land preparation

Ploughing, trench preparation, manuring, fertilization and intercultural operations are described as Experiment 2.

3.5.5 Sett

3.5.5.1 Sett collection

Setts of sugarcane varieties Isd 34 and Isd 36 were collected from Joypurhat Sugar Mills Limited experimental farm. These varieties were released in 2002 and 2003 from BSRI, Ishurdi, Pabna and its Parentage were introduced from India and CP 70-1133 x ? (Polycross in other variety) {CP = Canal Point (Florida) 1965, selection 357}.

Sett preparation, sett treatment, sett placement and intercultural operations were same as described in Experiment 2.

3.5.6 Data collection

The effect of different treatments in controlling and reducing sugarcane stem borer infestation was evaluated on the basis of infestation of stem and internode bores and subsequent yield per hectare. Data collection procedures were same as described in Experiment 2.

3.5.7 ECONOMIC ANALYSIS OF MANAGEMENT PACKAGE

Economic analysis in terms of Benefit Cost Ratio (BCR) was analyzed on the basis of total expenditure of the respective management package along with the total return from that particular package. In this study BCR was analyzed for a hectare of land.

For this analysis following parameters were considered:

3.5.7.1 Treatmentwise management cost/variable Cost: This cost was calculated by adding all costs incurred for labors and inputs for each management package including untreated control during the entire cropping season. The plot yield (kg $plot^{-1}$) of each package was converted into ton ha^{-1} yields.

3.5.7.2 Gross Return (GR): The yield in terms of money that was measured by multiplying the total yield by the unit price of sugarcane (Tk 2750 ton^{-1}).

3.5.7.3 Net Return (NR) = The Net Return was calculated by subtracting treatmentwise management cost from gross return.

3.5.7.4 Adjusted Net Return (ANR): The ANR was determined by subtracting the net return for a particular management package from the net return with untreated control plot. Finally, BCR for each management package was calculated by using the following formula described by Elias and Karim (1984):

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}}$$

3.5.8 Statistical analysis

All the collected data were subjected to proper statistical analysis. The percentage data was subjected to ArcSin transformation while the data in number was subjected to square root transformation as and when needed. The data was analyzed by using MSTAT-C statistical package programme. Analysis of variance (ANOVA) was done by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Graphical interpretations were also performed wherever needed.

Chapter IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from different experiments have been presented sequentially, interpreted and discussed as revealed the findings systematically in line of targeted objectives of the study.

4.1 Pest status and infestation intensity of sugarcane stem borer in major sugarcane growing regions of Bangaladesh

4.1.1 Profile of sugarcane growers

The profile of 100 growers in 15 upazilas of nine districts under 8 sugar mills zone of Bangladesh has been discussed in this section.

4.1.1.1 Age of the farmers

The age of sugarcane growers varied between 17 to 65 years with average of 42.46 years (Figure 4.1.18). Among the growers, 11%were below 20 years old, 21% were 21-35 years old, 37% were 36-50 years old and 31% farmers were 51-65 years old (Figure 4.1.19). It was clear from the study that most of the growers (68%) were 36-65 years old.

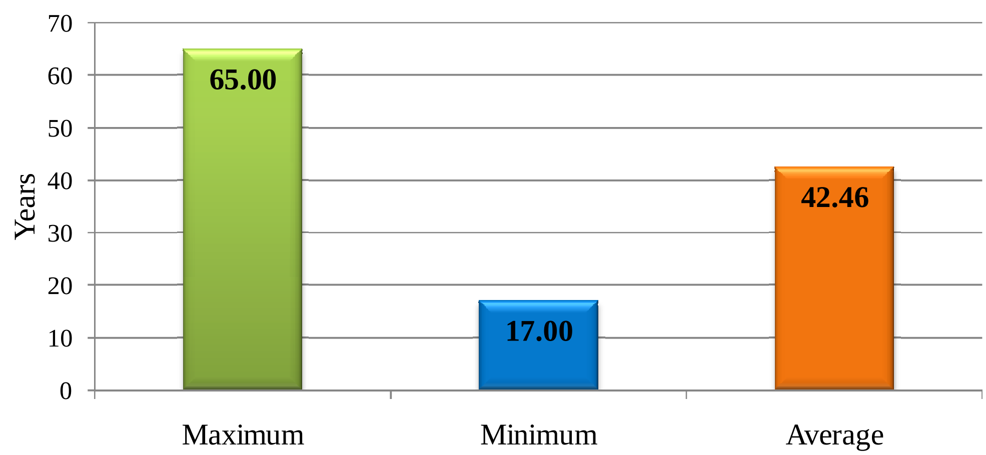


Figure 4.1.18 Maximum, minimum and average age of the growers cultivating sugarcane.

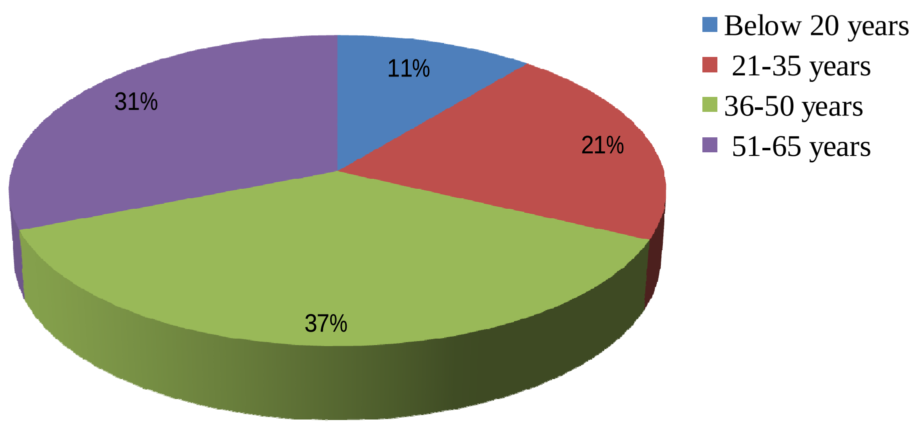


Figure 4.1.19 Age distribution of growers cultivating sugarcane.

4.1.1.2 Education

The education status of the sugarcane growers was varied from no education to graduate level. Most of the farmers (30%) had primary education followed by 29% had secondary education, 20% had higher secondary, only 5% had graduate level education and considerable percentage (16%) of growers had no institutional education (Figure 4.1.20).

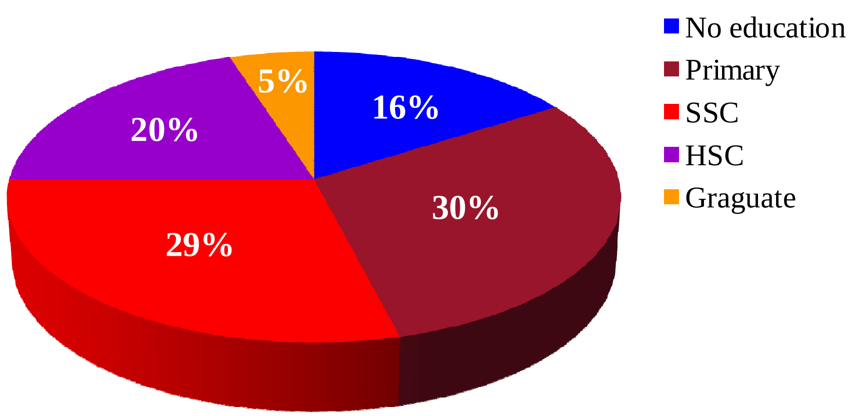


Figure 4.1.20 Education status of the sugarcane growers under study.

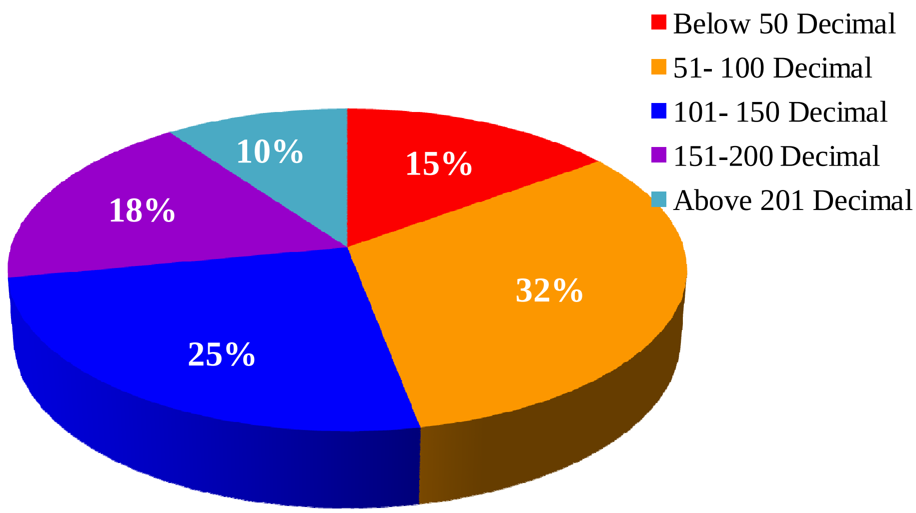


Figure 4.1.21 Farmer's response on sugarcane cultivation area.

4.1.1.3 Sugarcane cultivation land of the farmers

Among the farmers, 15% had below 50 decimal sugarcane cultivable land area, 32% farmers had 51-100 decimal, 25% farmers had 101-150 decimal and only 10% farmers had above 200 decimal lands under sugarcane cultivation. Thus, most of the farmers (72%) had less than 150 decimal of sugarcane cultivable land (Figure 4.1.21).

4.1.1.4 Farmers’ membership of professional organization

Farmers’ opinions revealed that 100% farmers were the member of different farmer’s society. Most of them (90.09%) were member of the Akh chashi Kollyan Sommittee and 4.50% were BSRI selected farmers and 5.41% DAE selected farmers (Figure 4.1.22).

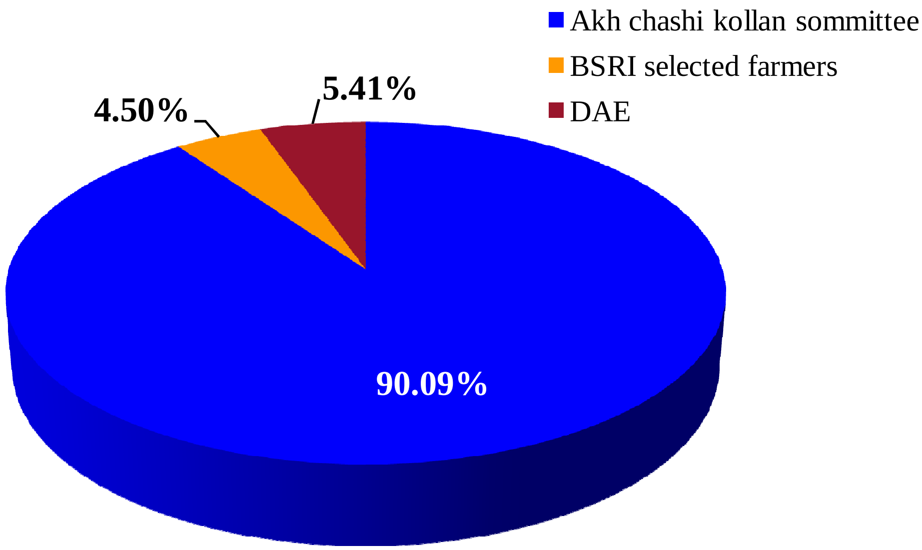


Figure 4.1.22 Farmer's membership of the profesional organizations**.**

4.1.1.5 Farmers' training on sugarcane cultivation

Out of 100 farmers, 3% opined that they had no training on sugarcane cultivation and 97% farmers had professional training on sugarcane cultivation (Figure 4.1.23). Most of the farmers trained up from one or more organization (multiple responses) at a time.As per opinion 97% farmers had traning from sugar mills, 26 farmers had training the Bangladesh Sugarcrop Research Institute (BSRI) and 7 farmers had training sponsored by the Department of Agriculture Extension (DAE). Among them, 98 farmers trained from one organization and 26 farmers trained from two organizations and 6 farmers trained from three organizations (Appendix 4.1.6). The result revealed that most of the sugarcane growers have training on sugarcane cultivation and they apply their training knowledge for increasing the sugarcane production. A total of 74.62% farmers opined that they got training from sugar mills. This result indicated that most of the sugarcane growers were trained from sugar mills. BSRI and DAE training on sugarcane cultivation occupied 20% and 5.38% of total respondent, respectively (Figure 4.1.24).

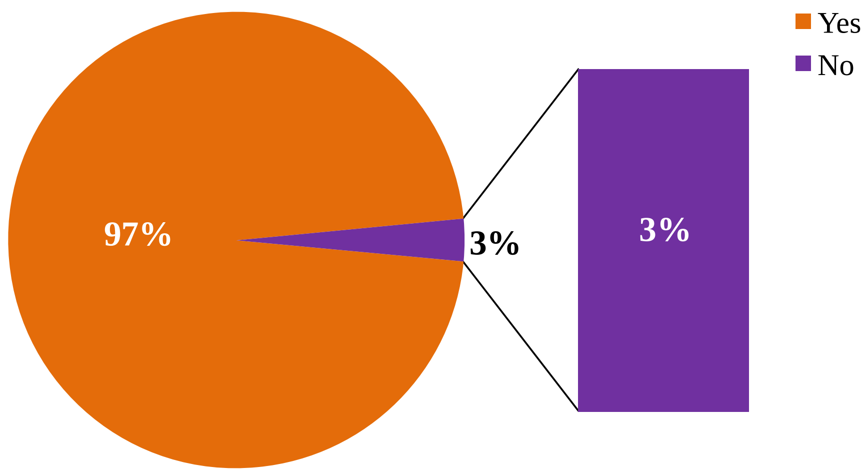


Figure 4.1.23 Farmer's response about training on sugarcane cultivation.

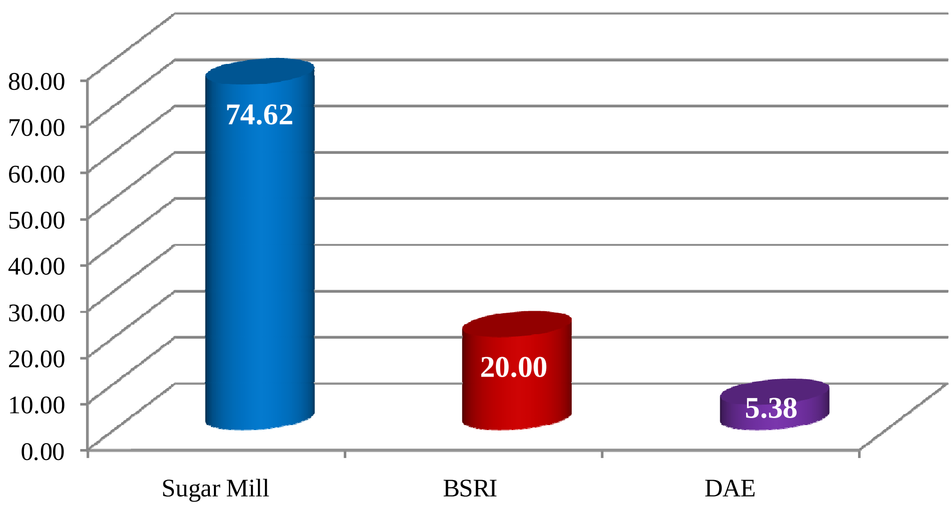


Figure 4.1.24 Farmers having training on sugarcane cultivation from different organizations.

4.1.1.6 Experience of sugarcane cultivation

Sugarcane cultivation experience of the farmers was varied from 3 to 45 years with 13.01 average and 6.98 standard deviation. However, 12% farmers had below 5 year sugarcane cultivation experience and 32% farmers had 5.01-10.0 year sugarcane cultivation experience (Figure 4.1.25). 10.01- 15.00 and above 15.01 years sugarcane cultivation experienced farmers were 31% and 25%, respectively. Thus most of the farmers had 5 to

15 year sugarcane cultivation experience and they were very much skilled in sugarcane cultivation.

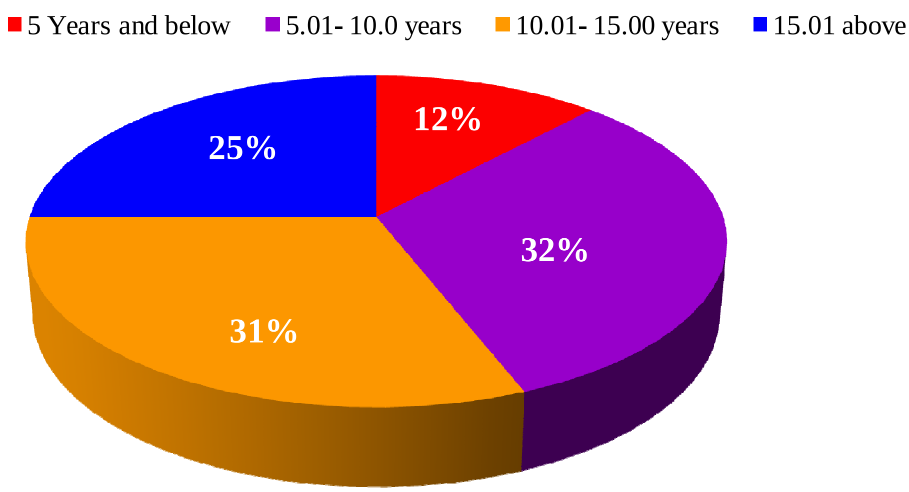


Figure 4.1.25 Farmers experience on sugarcane cultivation.

4.1.1.7 Farmer's information on sugarcane variety for cultivation

Sugarcane growers reported 12 cultivated varieties of sugarcane which were Isd 16, Isd 20, Isd, Isd 26, Isd 33, Isd 34, Isd 36, Isd 37, Isd 38, Isd 39, Isd 40, BSRI Akh 43 and BSRI Akh 44. Of which Isd 34 was the most popular variety cultivated by 31% farmers. The next popular variety was Isd 33 reported by 30 % farmers. Isd 37 was cultivated by only 16% farmers. Most of the farmers cultivated two or more varieties (multiple responses) at a time. Among them, 52 farmers cultivated two varieties and 13 farmers cultivated three varieties of sugarcane in different fields. A total of 24.85% farmers opined that they cultivated Isd 34 variety (Table 4.1.9). This result indicated that Isd 34 was the most preferable cultivated variety of sugarcane in Bangladesh and Isd 33 and Isd 37 were second most popular variety which occupied 20.61% of total respondent in both cases. The results support the reports of BSFIC (2012) where different cultivated varieties of sugarcane were reported.

Table 4.1.9 Farmers' response on cultivation of different sugarcane varieties

Name of varieties	Respondents to cultivating the number of sugarcane variety				% Respondents
	One variety	Two varieties	Three varieties	Total	
Isd 16	4	0	0	4	2.42
Isd 20	3	0	0	3	1.82
Isd 26	8	0	0	8	4.85
Isd 33	30	4	0	34	20.61
Isd 34	31	10	0	41	24.85
Isd 36	1	3	0	4	2.42
Isd 37	16	16	2	34	20.61
Isd 38	0	1	2	3	1.82
Isd 39	7	15	8	30	18.18
Isd 40	0	3	0	3	1.82
BSRI Akh 44	0	0	1	1	0.61
Total	**100**	**52**	**13**	**165**	**100**

4.1.1.8 Sources of sugarcane seed used by the farmers for cultivation

Sugarcane farmers used seeds from different sources for cultivation of sugarcane. Among those 84% farmers used their own seeds, 15% farmers collected seeds from other farmers directly and 1% farmers collected seeds from sugar mill (Appendix 4.1.7). Among the different sources of seeds, most of the farmers used sugarcane seed of single source but 23 farmers used seeds of two different sources. In case of multiple responses a total of 68.29% used seeds of their own and 26.83% farmers collect other farmer's seeds and 4.88% used sugar mill's seed (Figure 4.1.26). The results indicated that farmers own seeds, other's farmer seed and sugar mill's seeds are the main sources of sugarcane seeds for cultivation. It is essential to supply sugarcane seeds of high yielding varieties from reliable source for better production of sugarcane in Bangladesh which will increase yield.

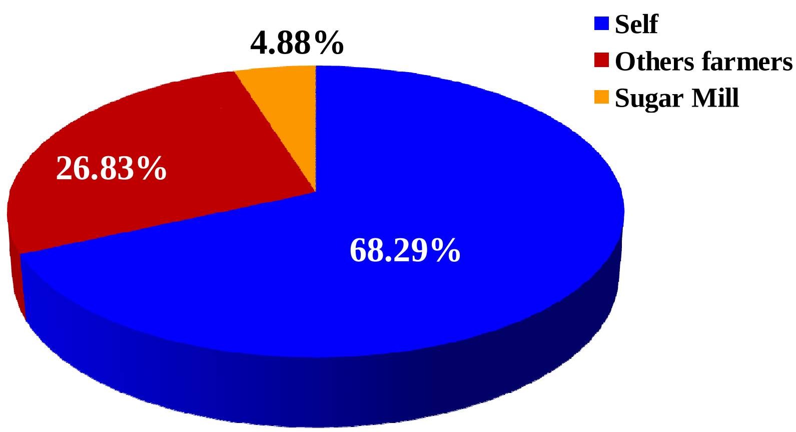


Figure 4.1.26 Source of sugarcane seeds for cultivation.

4.1.1.9 Farmers response on problems of sugarcane in field

Problems of sugarcane production such as long duration crop, low price, insect pest infestation, disease infection, low yield, delay payment cane price and high labor cost are commonly faced by the sugarcane farmers. Most of the farmers responded three or more problems (multiple responses) at a time during sugarcane production. In case of single response, 18.68% farmers opined that low price was the main problem for sugarcane production and low yield was considered as second problem by 18.11% farmers. Insect pest's infestation was the third major problem for sugarcane production reported by 16.42% farmers and 9.81% farmers reported sugarcane disases as major problem. More than 69% farmers replied that problems for sugarcane cultivation as long duration crop, low price, insect pests infestation and low yield (Figure 4.1.27).

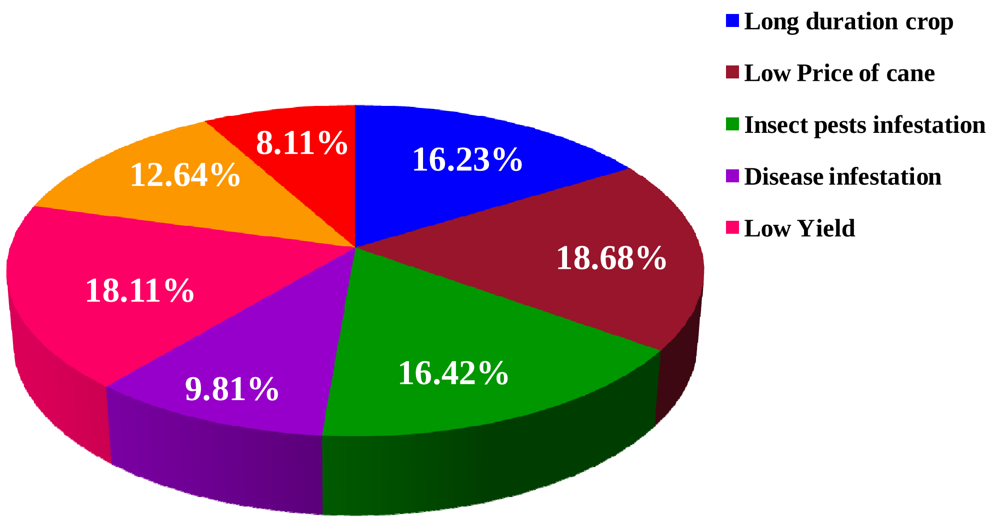


Figure 4.1.27 Problems on sugarcane cultivation**.**

Most of the farmers (86) opined that long duration of crop was the first and main problem for sugarcane production and 14 farmers reported low price as the first and main problem for sugarcane cultivation. Twelve farmers and 75 farmers opined insect pest infestation was the second and third problems for sugarcane production. So, insect pest infestation is the one of major problem for sugarcane production. Most of the farmers responded several problems at a time. One hundred, 100, 99, 95, 82 and 54 farmers responded as 1st, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} problem of sugarcane cultivation in field, respectively (Table 4.1.10).

Table 4.1.10 Farmers' response on problems in sugarcane cultivation in Bangladesh

Problems	Number of respondents to identify the problem							% Response
	First problem	2nd problem	3rd problem	4th problem	5th problem	6th problem	Total	
Long duration	86	0	0	0	0	0	86	16.23
Low price	14	85	0	0	0	0	99	18.68
Insect pests infestation	0	12	75	0	0	0	87	16.42
Disease	0	2	10	40	0	0	52	9.81
Low yield	0	1	14	42	39	0	96	18.11
Delay cane price payment	0	0	0	11	28	28	67	12.64
High labor cost	0	0	0	2	15	26	43	8.11
Total	**100**	**100**	**99**	**95**	**82**	**54**	**530**	**100**

Table 4.1.11 Farmer's information on incidence of insect pests of sugarcane in field

Name of pests	Number of respondents to identify the incidence of pests							**% response**
	First pest	**Second pest**	**Third pest**	**Fourth pest**	**Fifth pest**	**Sixth pest**	**Total**	
Stem borer	100	0	0	0	0	0	100	31.85
Top shoot borer	0	93	0	0	0	0	93	29.62
Early shoot borer	0	2	32	0	0	0	34	10.83
Termite	0	2	35	17	0	0	54	17.2
Rodent	0	2	6	13	4	0	25	7.962
Root stock bore	0	0	0	0	1	0	1	0.318
Scale insect	0	0	2	4	0	1	7	2.229
Total	**100**	**99**	**75**	**34**	**5**	**1**	**314**	**100**

4.1.1.9.1 Farmers' response on insect pests of sugarcane in field

Farmers opined (multiple responses) that insect pests were one of the major problems during sugarcane production. Six insect pests were reported such as stem borer (SB), top shoot borer (TSB), early shoot borer (ESB), termite, root stock borer (RSB) and scale insect. Majority of farmers reported (31.85%) stem borer as a pest of sugarcane followed by 29.62%, 17.20% and 10.83% farmers reported top shoot borer, termite and early shoot borer respectively (Figure 4.1.28). Bergvinson (2004) reported root borer, early shoot borer, pyrilla, Gurudaspur borer, top shoot borer and sugarcane white fly as major insect pest of sugarcane.

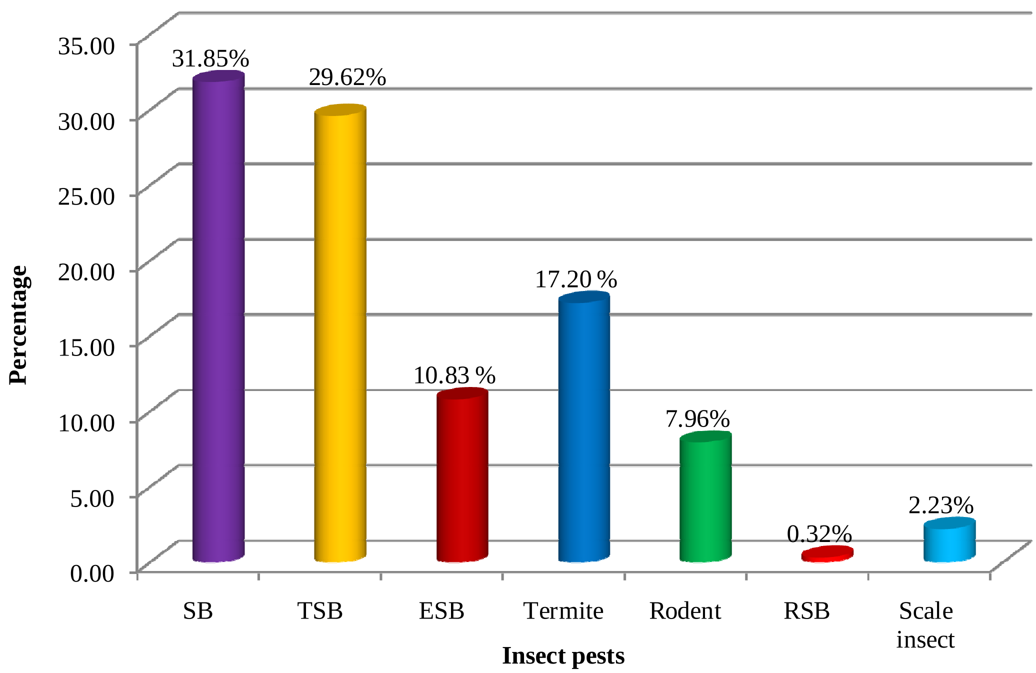


Figure 4.1.28 Response of farmers to the incidence of insect pests of sugarcane during its cultivation and production.

In case of multiple responses, all farmers (100) reported the stem borer as the first and main insect pest of sugarcane and top shoot borer as the second important pest by farmers (93) (Table 4.1.11). Termite and early shoot borer were reported as third major insect pests by 35, 32 farmers, respectively.

4.1.1.9.2 Disease

Disease was also one of the major problems for sugarcane cultivation among them red rot, smut, white leaf and wilt were the main diseases. As multiple responses, 41.26% farmers responded that red rot were the major disease. Smut and white leaf were reported as the second importrant diseases by responded 27.67% farmers. Only 3.40% farmers responded about wilt disease of sugarcane (Figure 4.1.29). Out of 100 farmers, 85 opined that the red rot as the major disease of sugarcane (Table 4.1.12).

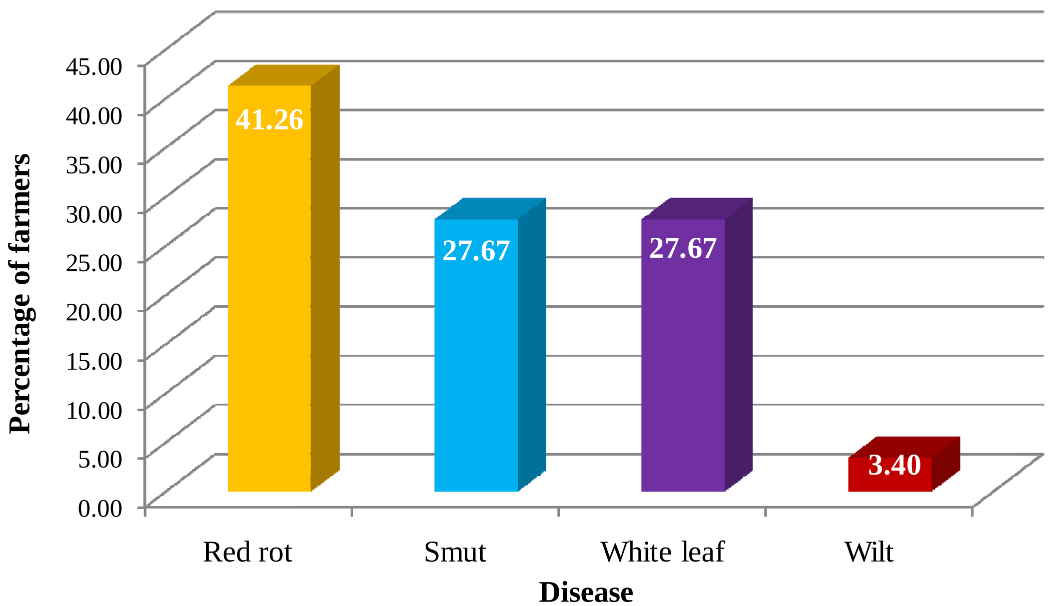


Figure 4.1.29 Response of farmers on the incidence of diseases of sugarcane in field.

Table 4.1.12 Farmer's response on the incidence of diseases in sugarcane in field cultivation

Disease	Number of farmers responded to the incidence of disease					(%) Respondents
	First disease	Second disease	Third disease	Fourth disease	Total	
Red rot	85	0	0	0	85	41.26
Smut	9	48	0	0	57	27.67
white leaf	3	25	29	0	57	27.67
Wilt	0	0	1	6	7	3.40
Total	**97**	**73**	**30**	**6**	**206**	**100**

4.1.1.10 Sugarcane yield losses by stem borer

Sugarcane stem borer caused serious damage on sugarcane in the field during growing season. All the farmers responded that stem borer infestation cause losses at various quantity (Appendix 4.1.8). Half of the total farmers (50%) reported 10.01-15.0% yield loss of sugarcane due to stem borer infestation and 5.01-10.0%, 1.00-5.0% and 15.01-20.0% yield loss was stated by 32%, 12% and 6% farmers, respectively (Figure 4.1.30).

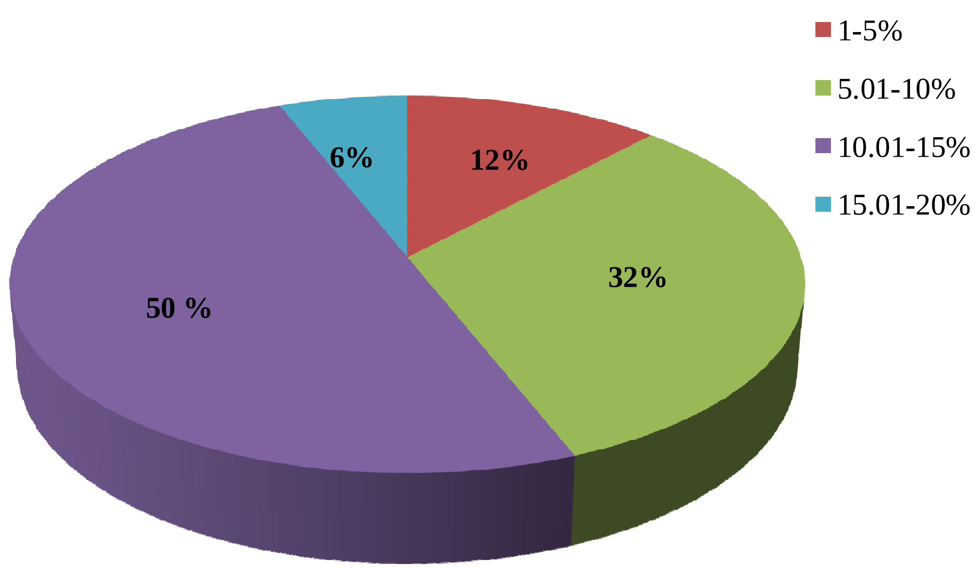


Figure 4.1.30 Farmer's response on sugarcane yield losses due to stem borer.

4.1.1.11 Farmers' response on the control measurs applied against sugarcane stem borer

4.1.1.11.1 Control measurs

Three control measures were reported to practice by farmers such as cultural (burning of leaves after harvest, detrashing etc), mechanical (cutting of infested cane and destruction of larva) and chemical control measures. Half of the total farmers (50.00%) opined that they controlled stem borer using chemical insecticides (Figure 4.1.31), 39.50% farmers reported that they cut infested cane and removed from the field when infestation occurred by stem borer (mechcanical control) and 10.50% farmers practided cultural control measures.

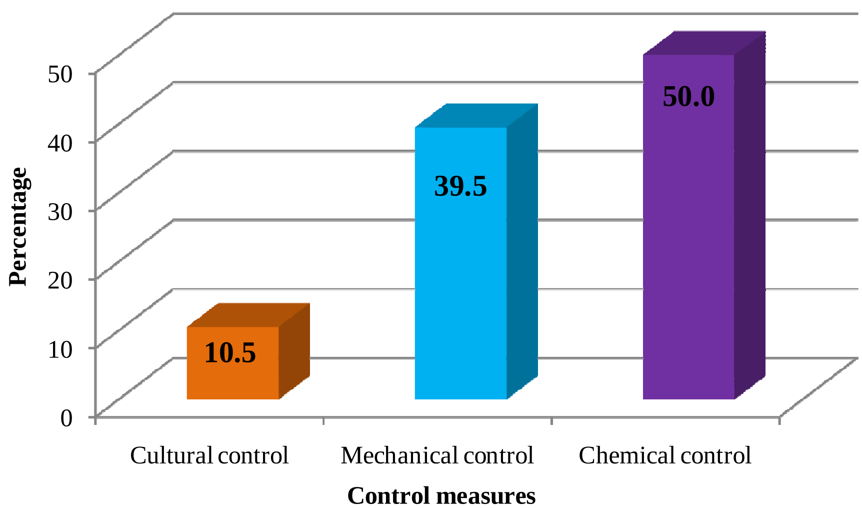


Figure 4.1.31 Farmers' response to practice on different control measures to manage sugarcane stem borer in the field**.**

Out of 100 farmers, 58 practiced mechanical control measures as the first control method against stem borer. A total of 100 farmers practiced the chemical control method in case of multiple responses (Table 4.1.13).

Table 4.1.13 Farmer's response on different control measures applied against sugarcane stem borer in the field

Control measures	Number of respondents to use control measure				% Respondents
	First control measures	Second control measures	Third control measures	Total	
Cultural control	21	0	0	21	10.50
Mechanical control	58	21	0	79	39.50
Chemical control	21	58	21	100	50.00
Total	**100**	**79**	**21**	**200**	**100**

4.1.1.11.2 Types of chemical insecticides

Farmers mainly used three kinds of insecticides such as carbofuran, virtako and lorsban to control the stem borer. Seventy nine (79) farmers responded that one type of chemical used against stem borer in sugarcane, 24 and 02 farmers practiced two or three types of chemicals, respectively to control stem borer in the field (Appendix 4.1.9). Most of the farmers (75.24%) used carbofuran and found effective chemical to control stem borer. Virtako and lorsban were also used to control stem by 18.10% and 6.67% farmers, respectively (Figure 4.1.32).

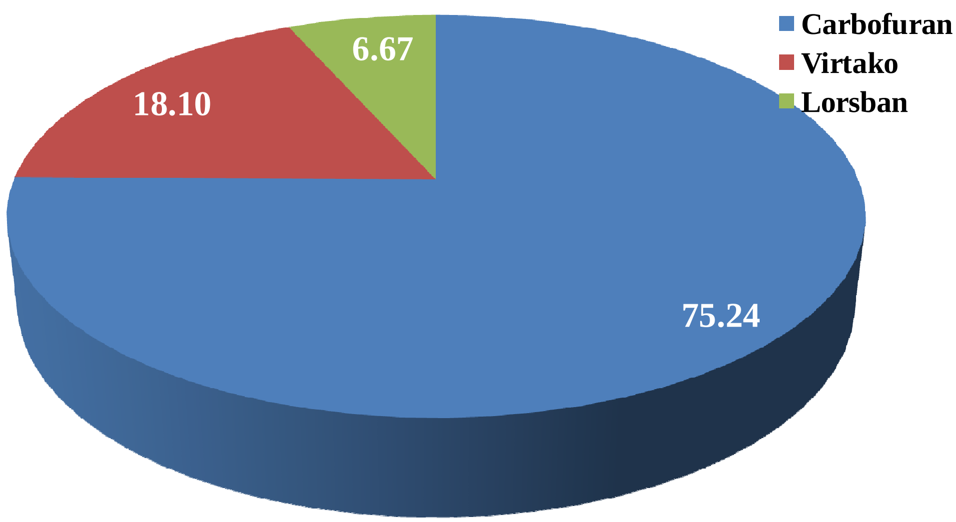


FIGURE 4.1.32 Farmer's response to apply chemical insecticide against stem borer.

4.1.1.12 Farmers response on the relationship between red rot and stem borer

Out of 100 farmers 63% opined that they didn't know the relationship between red rot infection and stem borer infestation but 37% farmers stated the relationship between red rot infection and stem borer infestation during sugarcane cultivation (Figure 4.1.33).

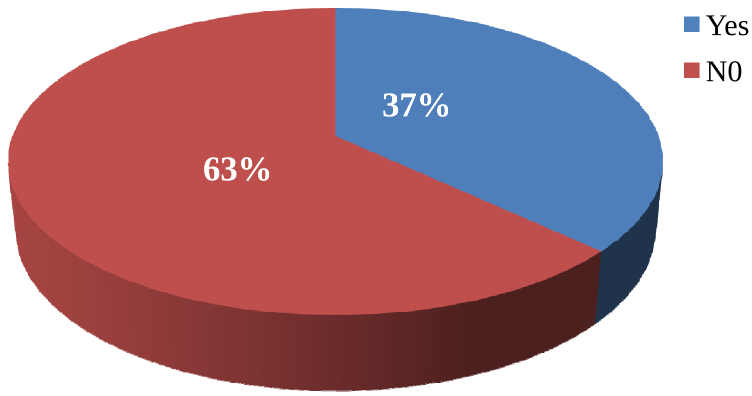


Figure 4.1.33 Farmers response on the relationship between red rot and stem borer infestation.

4.1.2 Stem borer infestation in farmer's field

Result on stem and internode infestation of sugarcane by *C. tumidicostalis* and number of larvae per plant in farmers field at different regions under survey have been presented in Table 4.1.14. Data indicated that percent stem infestation of *C.tumidicostalis* varied from 12.44% -17.20% at different locations under survey. The highest rate of stem infestation (17.20%) was observed in Ishurdi upazila of Pabna district under North Bengal Sugar Mill (NBSM) in Natore district. The second highest rate of stem infestation (15.07%) was documented in Chougacha upazila of Jessore district under MKSM (Table 4.1.14). Conversely, the lowest rate of stem infestation (12.44%) was found in Sadar upazila of Natore district under Natore Sugar Mill's (NTSM).

Data in table 4.1.14 also express that percent internode infestation was varied from 18.63% to 25.20% at different locations under study. The lowest percentage of internode infestation (18.63%) was recorded in Poba upazilla of Rajshahi district under Rajshahi Sugar Mill's (RJSM) as against the highest (25.50%) in Sadar upazila of Pabna district under Pabna Sugar Mill's (PBSM). Number of larva per infested plant in farmers field was also varied from 30.17-43.33 at different locations. The lowest number of larva (30.17 $plant^{-1}$) was recorded from Kaliganj upazila of Jhenaidah district under Mobarakgonj Sugar Mill's (MKSM) and the highest number of larva (43.33 $plant^{-1}$)was observed in Sadar upazila of Joypurhat district under JSM.

This finding partially agrees with the reports of several researchers in Bangladesh. Begum *et al.* (2006) reported 27.52% stem borer infestation at BSRI farm, Ishurdi, Pabna in November 2005. Abdullah *et al.* (2004) reported that stem borer, *C. tumidicostalis* infestation ranged from 14.54 to 33.74% (stalk basis). In another report Abdullah *et al.* (2006) stated 5.25 to 55.21% stem borer infestation. Alam (1967) reported that stem borer alone caused 20-60% infestation under the field condition. However, 100% infestation was recorded in Setabgonj sugar mill's (Karim and Islam, 1977). This result did not agree with report of Rahman *et al*. (2013) who observed 23-36% stem infestation by *C.tumidicostalis* in different AEZ of Bangladesh. Field survey result which found in this study is logical because borer infestation may vary with climatic factors and geographic location. Ulla *et al.* (2006) reported 10.00% stem infestation by stem borer in Punjab, Pakistan.

Table 4.1.14 Field survey data on % SB infested cane, % internodes infestation and number of larva per plant at 15 upazilla of 9 districts under 8 sugar mills during July – August 2014

Sugar Mills	District	Upazilla	% SB infestation	% Internode infestation	Larva per plant
RJsm	Rajshahi	Puthia	14.20±1.37	19.35±0.51	38.60±8.50
		Poba	14.00±0.71	18.63±1.23	35.77±6.15
NTSM	Natore	Natore sadar	12.44±1.28	20.37±2.66	32.25±4.97
NBSM	Pabna	Ishordi	17.20±4.24	23.16±0.87	38.07±4.52
PBSM		Pabna	12.93±1.40	25.20±0.91	32.62±2.08
Carew and Co	Kustia	Kustia	14.53±1,24	24.46±0.66	33.17±5.50
MKSM	Jhenaidah	Kaliganj	13.06±0.72	22.43±1.04	30.17±1.17
		Kotchadpur	12.89±1.47	22.62±1.23	31.67±2.02
	Jessore	Chougacha	15.07±1.80	23.29±1.83	32.73±4.10
		Jessore	13.33±1.40	22.97±2.58	41.20±3.11
JSM	Joypurhat	Joypurhat sadar	13.00±0.62	23.51±0.89	43.33±2.83
	Naugoan	Dhamurhat	14.13±1.12	21.96±1.78	38.30±6.84
STSM	Dinajpur	Kaharol	14.93±1.14	25.05±0.46	33.70±2.17
		Birganj	13.87±1.56	22.13±1.71	34.47±4.72
		Dinajpur sadar	13.60±1.92	20.67±2.83	32.70±3.92

4.1.3 Stem borer infestation in experimental plots at Ishurdi, Pabna

Infestation intensity of *C. tumidicostalis* was documented in experimental plots at Bangladesh Sugarcrops Research Institute (BSRI), Ishurdi, Pabna in 2014, 2015 and 2016.

4.1.3.1 Infestation intensity of *C. tumidicostalis* in the experimental plots where infested canes were cut and removed from the field after one month interval

Stem and internode infestation percentage by *C. tumidicostalis* and number of larvae per plant in the experimental plots where infested stem was cut and removed at one-month interval have been presented and discussed here. Infestation that recorded in every month was considered as new infestation.

4.1.3.1.1 Stem infestation

Percent stem infestation by *C. tumidicostalis* in experimental fields where infested stem was cut and removed atr one month interval during 2014, 2015 and 2016 is shown in Figure 4.1.34. The graph revealed that *C. tumidicostalis* started infestation from May and increased gradually with the age of the crops up to September then declined and sharply declined after October and no new infestation occurred in November (Appendix 4.1.10). The peak infestation of *C. tumidicostalis* was observed in September every year. Similar trends of stem infestation by *C. tumidicostalis* were observed in 2014, 2015 and 2016. The highest percentage of stem infestation was recorded in 2015 followed by 2014 and 2016.

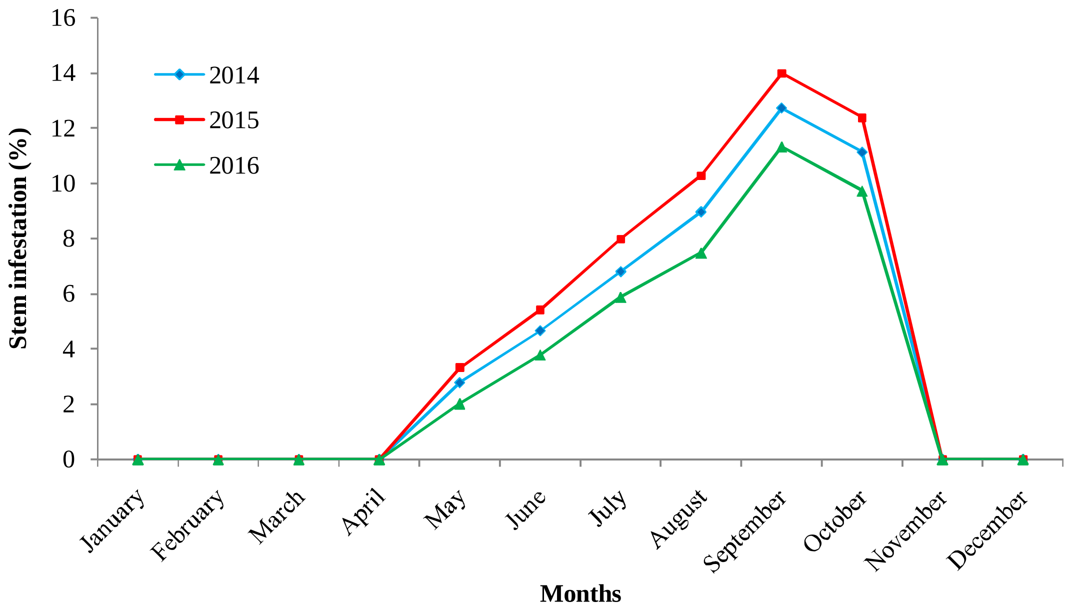


Figure 4.1.34 Trends of sugarcane stem infestation by *C. tumidicostalis* which were cut and removed from the field in 2014, 2015 and 2016.

4.1.3.1.2 Incidence of internode infestation

Trends of internode infestation per infested stem by stem borer in the experimental plots. Which were cut and removed at one month interval in 2014, 2015 and 2016 and presented in Figure 4.1.35. Figure revealed that the internode infestation was started from May and gradually increased with the age of the plant and reached to the peak in September then declined and no new internode infestation occurred in November (Appendix 4.1.11). Similar trend for internode infestation was observed in 2014, 2015 and 2016. But the highest internode infestation was recorded in 2014 followed by 2015 and 2016.

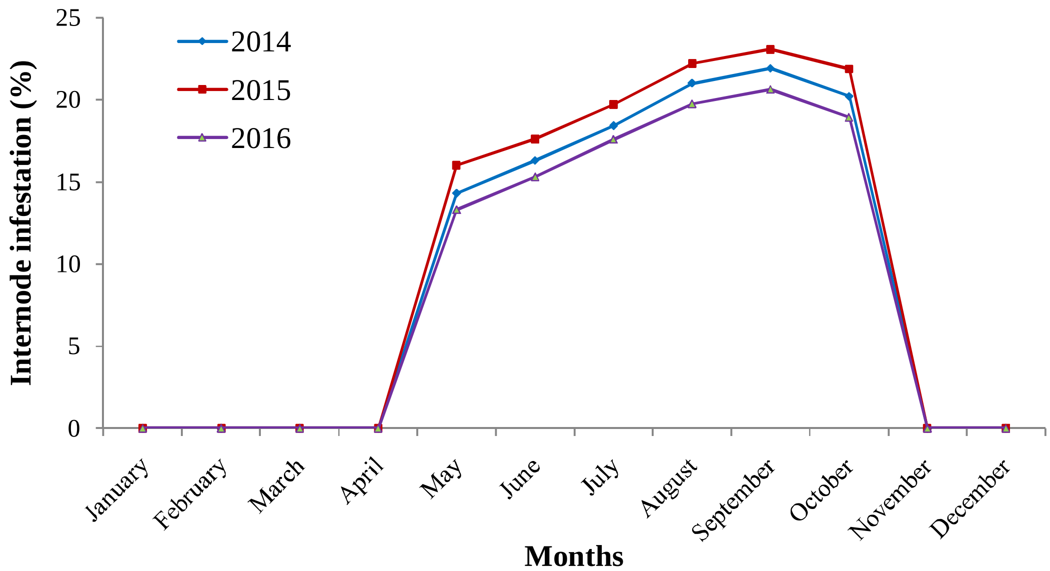


Figure 4.1.35 Trends of sugarcane internodes infestation of *C. tumidicostalis* on sugarcane in infested stem cutting field in 2014, 2015 and 2016.

4.1.3.1.3 Number of larva per infested plant

Number of larva of *C. tumidicostalis* per infested stem in the plots which were cut and removed at one month interval in 2014, 2015 and 2016 and was shown in Figure 4.1.36. Borer larva was first observed in May every year. Figure demonstrate that the number of larva per plant was high initially when infestation started in May then gradually decreased and reached to the minimum level in October and no new larva was found afterward (Appendix 4.1.12). The highest number of larva/plant was observed in 2015 followed by 2014 and 2016.

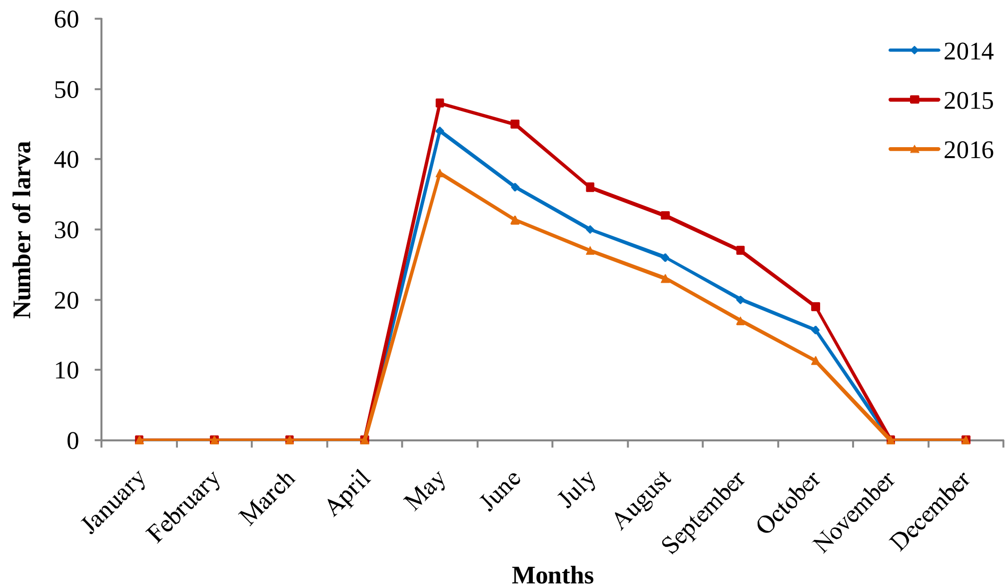


Figure 4.1.36 Trends of number of larva in infested cane by *C. tumidicostalis* on sugarcane in infested stem cutting field in 2014, 2015 and 2016.

4.1.3.2 Infestation intensity of *C. tumidicostalis* in the experimental plots where infested canes were kept in the field

Stem and internode infestation of *C. tumidicostalis* and number of larvae per plant in the experimental plots where infested stems left in the field have been presented and discussed here. Infestation that recorded in each month was considered as cumulative infestation.

4.1.3.2.1 Stem infestation

Percent stem infestation of *C. tumidicostalis* in experimental fields which were left untouched in the field during 2014, 2015 and 2016 and shown in Figure 4.1.37. *C. tumidicostalis* infestation was started from May in every year. Initially, infestation percentage was low and gradually increased with age of the crop and reached to the maximum level in October. Then percent infestation was static because of no new infestation occurred in November (Appendix 4.1.13). The highest level of infestation was recorded in 2014 followed by 2015 and 2016.

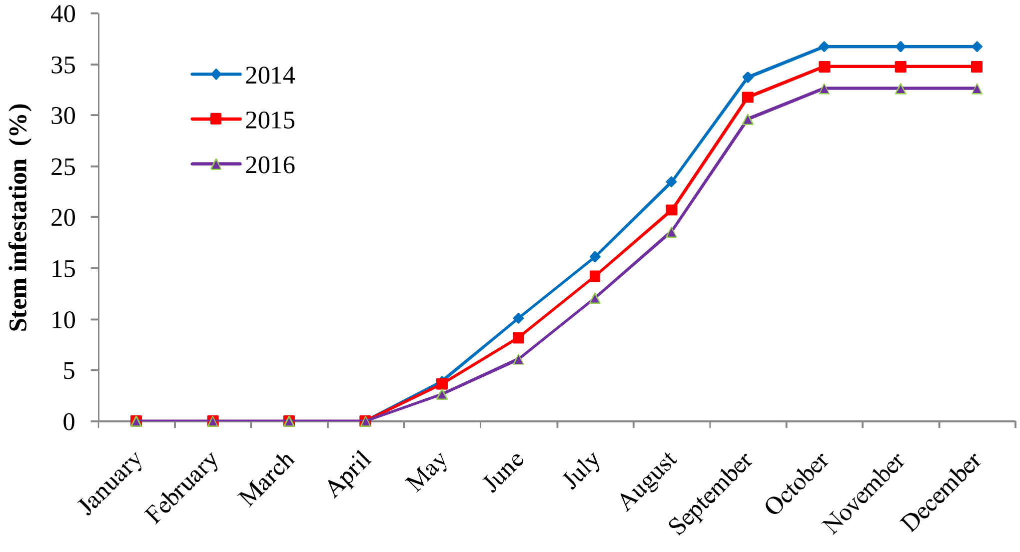


Figure 4.1.37 Trends of sugarcane stem infestation by *C. tumidicostalis* in experimental plots where infested stem were left in the field in 2014, 2015, 2016.

Stem infestation was done of *C. tumidicostalis* in the experimental fields during 2014, 2015 and 2016 which were considered as cumulative infestation (infested stems kept in the field) have been presented in Figure 4.1.38. Stem infestation by *C. tumidicostalis* varied from 20.88% to 24.71%. Lowest infestation (20.88%) was observed in 2016 and highest level of infestation (24.71%) was recorded in 2014.

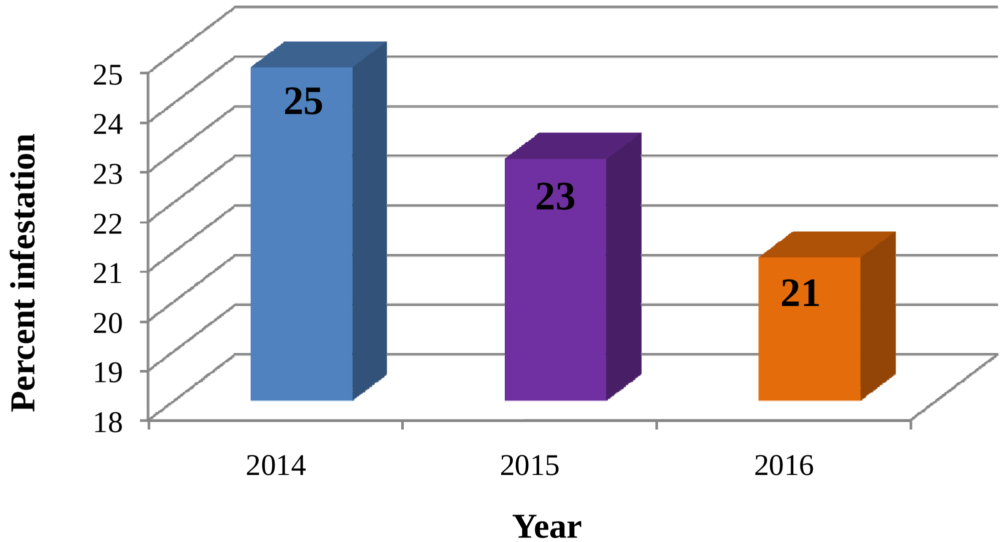


Figure 4.1.38: Percent plant infestation by *C. tumidicostalis* in experimental plots as cumulative infestation in 2014, 2015, 2016.

4.1.3.2.2 Internode infestation

Percent internode infestation by *C. Tumidicostalis* in experimental fields and left infested stemsremain untouched in the field in 2014, 2015 and 2016 and shown in Figure 4.1.39. Figure revealed that internode infestation was started from May and gradually increased with the age of the plant and reached to the peak in October. Then percent internode infestation was remained constant as no new infestation occurred in November (Appendix 4.1.14). Similar trend for internode infestation was observed in 2014, 2015 and 2016. But the highest internode infestation was recorded in 2015 followed by 2015 and 2016.

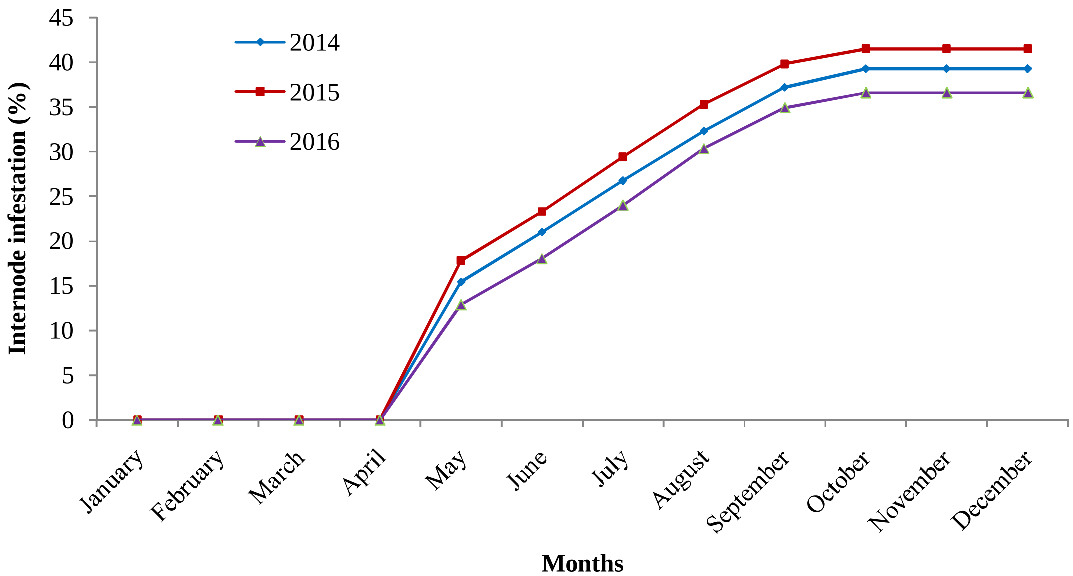


Figure 4.1.39 Trends of sugarcane internodes infestation by *C. tumidicostalis*in in experimental plots which were cut and removed in the field in 2014, 2015 and 2016.

4.1.3.2.3 Number of larva per infested plant

Number of larva of *C. tumidicostalis* per infested plant in the experimental plots where infested stem left in the field in 2014, 2015 and 2016 and shown in Figure 4.1.40. Borer larva was first observed in May every year. Figure demonstrated that number of larva per plant was high initially when infestation started in May then gradually it decreased and reached to the minimum level in October and no new larva was found afterward (Appendix 4.1.15). The highest number of larva per plant was observed in 2015 followed by 2014 and 2016.

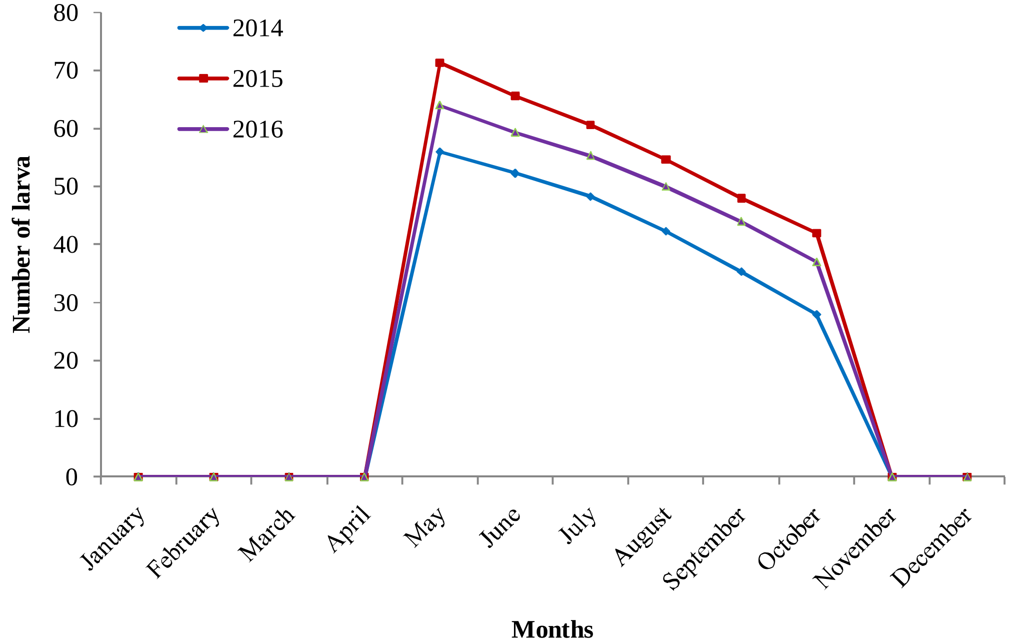


Figure 4.1.40 Trends of number of larva of *C. tumidicostalis*in infested cane in the experimental plots which were cut and removed in the field in 2014, 2015, 2016.

The above results indicated that the stem and internode infestation by *C. tumidicostalis* started from May when cane formation occurred, increased gradually with the age of the crop and reached to a peak in October. No infestation was observed in November and afterwards upto April. Number of larvae was found highest in May during early stage of infestation. Usually primary infestation of *C. tumidicostalis* started during last April or May, when stem formation occurred. The newly hatch larvae congregating in the top 3 to 5 internodes of a cane. As a result, large numbers of larva are available inside one stem. The grown-up larvae migrate to the adjoining canes or to the lower healthy portion of the canes and give rise to the “secondary attack”. In secondary infestation, small numbers of larva are available in stem. These results agree with the findings of Begum *et al.* (2006) who reported that *C. tumidicostalis* infestation initiated in May in every year. It was also found by Karim and Islam (1977) who observed *C. tumidicostalis* infestation initiated from the end of April and continued upto November and it was most abundant in June to September. Alam *et al.* (2005) stated that stem borer population consisted of larger instars larvae in June to August.

4.1.4 Relationship of percent cane infestation by *C. tumidicostalis* with temperature and rainfall

The relationships among percent plant infestation by *C. tumidicostalis* with temperature and rainfall in 2014, 2015 and 2016 are shown in Figure 4.1.41. Positive linear relationship was observed between percent cane infestation by *C. tumidicostalis* and average environmental temperature (^oC), and percent cane infestation with rainfall in three cropping seasons. High positive relationships were existed between percent cane infestation and temperature (^oC) with R^2 values 0.807, 0.697 and 0.545 in 2014, 2015 and 2016, respectively (Figure 3.1.28A, B, C). On the other hand low positive relationships were observed between percent cane infestation and rainfall with R^2 values 0.192, 0.175 and 0.113 in 2014, 2015 and 2016, respectively (Figure 4.1.41 A, B, C).

The result suggested that *C. tumidicostalis* infestation varied with environemental temperature and rainfall and it was highly dependent on temperature. It agrees with the findings of several researchers elsewhere. Gupta *et al.* (1981) reported that climatic factors are responsible for stem borer infestation of sugarcane. Mitra and Varma (1981) stated that climatic factors showed positive effect on the development of sugarcane stem borer. Atwal and Sidhu (1967) observed positive relationship of climatic factors on the population build up of sugarcane stem borer. Kalra (1967) also reported the strong relationship of the above parameters like temperature and rainfall and the higher incidence of stem borer (*C. tumidicostalis* Hampson) infestation on sugarcane. Pradhan and Bhatia (1956) also reported about the strong relationship of stem borer infestation with rainfall, relative humidity and temperature. Rainfall appears to favor borer multiplication. However, under drought condition, profuse egg lying takes place in the month of June.

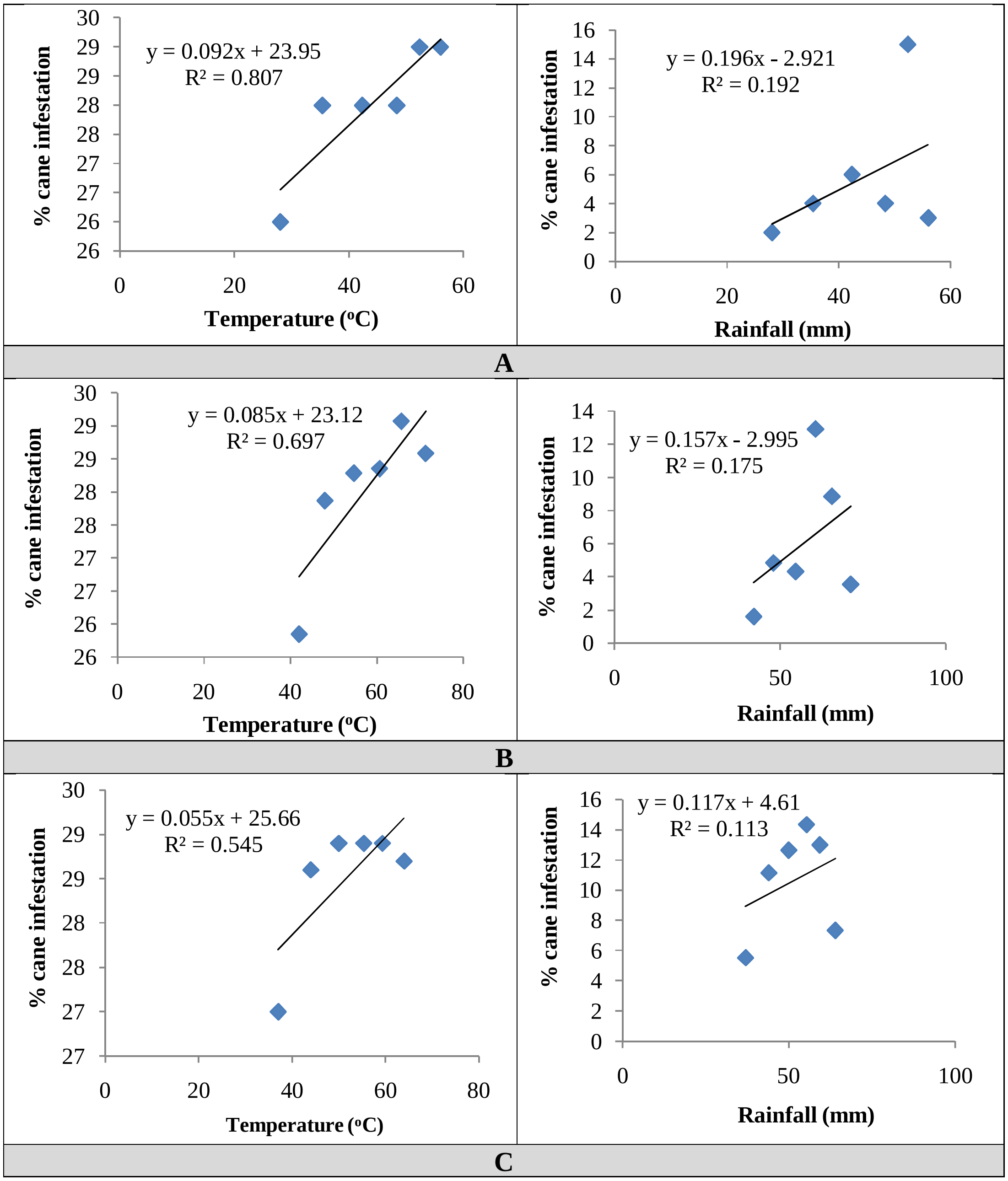


Figure 4.1.41 Relationship of sugarcane stem borer infestation with average temperature (^{o}C) in 2014 to 2016 A) 2014 B) 2015 and C) 2016.

4.2 Effeect of planting dates on the incidence and damage severity of sugarcane stem borer

4.2.1 Effect of different planting dates on stem borer infestation

4.2.1.1 Plant infestation

The effect of different planting dates on sugarcane stem borer infestation was significantly varied with various planting dates. A remarkable variation was also observed in number of healthy, infested and total canes in six planting dates. The number of healthy, infested and total canes per plot at six planting dates has been presented in Table 4.2.15. The highest number of healthy plants (250.30/plot) was recorded in T_3 treatment (planting on 15th November) having significant difference with other treatments. On the other hand, the lowest number of healthy plants (186.00/plot) was recorded in T_6 treatment (planting dates on 15th February), which was significantly lower than all other planting dates. The highest number of infested plants (41.00/plot) was recorded in T_1 treatment (planting dates on 15 September) having statistically different from other. The lowest number of infested plants (20.25/plot) was recorded in T_6 treatment (planting on15 February) having significantly lower than that of other treatments. Data (Table 4.2.15) also revealed that the highest number of total plants (272.30 plot^{-1}) was observed in T_3 treated plot. Conversely, the lowest number of plants (206.30 plot^{-1}) was obtained from T_6 treated plots (Planting dates on 15 February) having significant difference with other planting dates.

Table 4.2.15 Number of healthy, infested and total plants of sugarcane per plot recorded at six plantation dates

Treatments	Number of plants/plot		
	Healthy	**Infested**	**Total**
T_1= Plantingon 15 September	188.5 d	41.00 a	229.5 d
T_2= Planting on 15 October	217.8 c	37.00 b	254.8 b
T_3= Planting on 15 November	250.3 a	22.00 e	272.3 a
T_4= Planting on 15 December	229.5 b	28.50 c	258.0 b
T_5 = Planting n on 15 January	217.0 c	24.75 d	241.8 c
T_6= Planting on 15 February	186.0 d	20.25 f	206.3 e
$S_{\bar{x}}$	**1.440**	**0.2584**	**1.580**
C.V.%	**6.34**	**5.79**	**4.30**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

Percent plant infestation of sugarcane by *C.tumidicostalis* at different plantation dates has been presented in Figure 4.2.42. Figure revealed that the lowest percentage of plant infestation (8.08 %) was recorded in T_3 treatment (planting on 15 November) which was significantly different from all other planting times followed by T_6 (9.82%) treated plots (planting on 15 February). In contrast, the highest percent plant infestation (17.86%) was observed in T_1 treatment (planting on 15 September) which was significantly different from all other treatments (Appendix 4.2.16).

The result indicated that planting on 15 November (T_3) gave maximum number of healthy plant per plot and minimum infestation of *C. tumidicostalis*. Maximum infestation of stem borer occurred in early planted crops (T_1= plantingon 15 September, T_2= planting on 15 October). Early cane formation occurred in early planted crops and *C. tumidicostalis* started infestation earlier. Late planted crops had also lower level of *C. tumidicostalis* infestation because of delayed cane formation.The order of six planting times interms of percent plant infestation by *C. tumidicostalis* is 15 November (T_3) >planting on 15 February (T_6) > planting on 15 January (T_5)> planting on 15 December (T_4)> planting on 15 October (T_2 > plantingon 15 September (T_1).

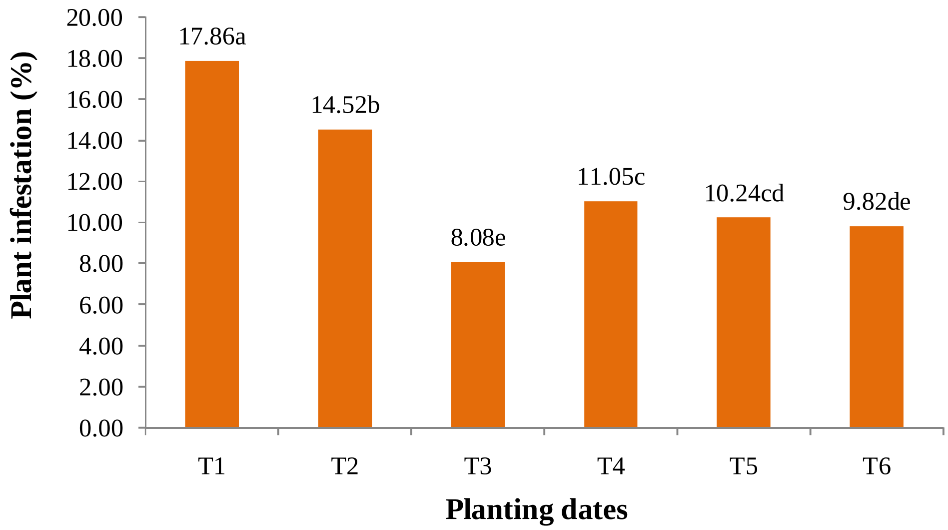


Figure 4.2.42. Sugarcane plant infestation percentage by *C. tumidicostalis* in 2015 at six planting dates.

[T_1= planting on 15 September, T_2= planting on 15 October, T_3= planting on 15 November, T_4= planting on 15 December, T_5 = planting on 15 January, and T_6= planting on 15 February].

4.2.1.2 Internode infestation

A remarkable variation was found in number of healthy, infested and total internodes plants^{-1} in different treatments. The number of healthy, infested and total internodes plants^{-1} per plot planted at different planting dates is shown in Table 4.2.16. The highest number of healthy internodes per plant (12.43) was recorded from T_3 treatment (planting date on 15 September) having significant variations with others. On the other hand, the lowest number of healthy internodes per plant (9.63) was recorded in T_6 treatment (Planting date on 15th February), which was significantly lower than all other treated plots. In contrast, the highest number of infested internodes per plant (4.34) was recorded from T_1 treatment (planting date on 15 September), which was significantly higher than all other planting date. The lowest number of infested internodes per plant (2.79) was recorded in T_6 treatment (planting date on 15 February) having significantly lower than other treatments. Data (Table 4.2.16) also express that the highest number of total internodes per plant (15.57) was observed in T_1 treated plot having significant different from others except T_3 treatment. The lowest number of total internodes per plant (12.43) was obtained from T_6 treatment (planting date on 15th February) having significant difference among other treated plots.

Table 4.2.16. Number of healthy, infested and total internodes per plant in 2015 at planting date

Treatments	Number of internodes per plant		
	Healthy	Infested	Total
T_1= Planting on 15 September	11.23 b	4.34 a	15.57 a
T_2= Planting on 15 October	11.10 b	3.50 b	14.60 bc
T_3= Planting on 15 November	12.43 a	2.85 c	15.27 ab
T_4= Planting on 15 December	10.56 bc	3.57 b	14.13 c
T_5 = Planting n on 15 January	10.26 cd	3.07 c	13.32 d
T_6= Planting on 15 February	9.63 d	2.79 c	12.43 e
$S_{\bar{x}}$	**0.1746**	**0.06519**	**0.1688**
C.V.%	**3.21**	**3.87**	**2.37**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

The effect of different date of plantation on percentage internodes infestation per plant of sugarcane is presented in Figure 4.2.43. The lowest percentage of internodes infestation (18.66 %) was recorded in T_3 treatment (planting date on 15th November) which was significantly different from all other planting dates. The highest plant infestation (27.87%) was observed in T_1 treatment (planting date on 15th September) which was significantly different from all other planting date, except T_4 (planting date on 15th December) treated plot (Appendix 4.2.17).

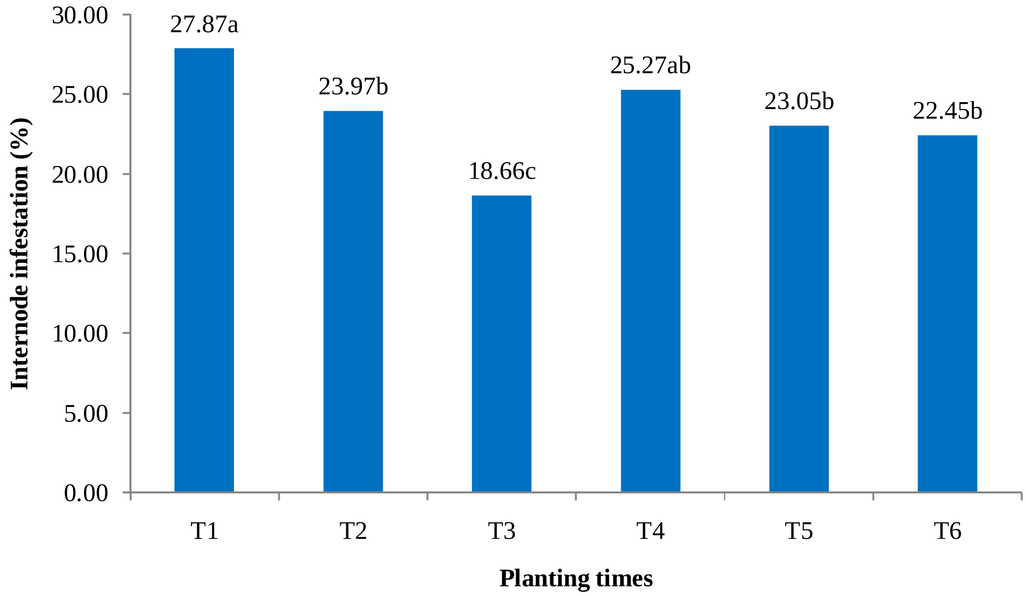


Figure 4.2.43 Sugarcane internodes infestation percentage by *C. tumidicostalis*in 2015 at six planting dates.

[T_1= plantingon 15 September, T_2= planting on 15 October, T_3= planting on 15 November, T_4= planting on 15 December, T_5 = planting on 15 January, and T_6= plantingon 15 February].

4.2.1.3 Yield of sugarcane at six planting dates

Healthy, infested and total cane yield of sugarcane significantly varied at six planting dates. The highest healthy cane yield (84.41 t/ha) was obtained from T_3 (planting on 15 November) having significant difference with other dates (Table 4.2.17). In contrast the lowest healthy cane yield (50.18 t/ha) was recorded from T_6 (planting on 15 February) which was significantly lower than other planting dates. No significant variation was observed among T_2 (planting on 15 October) and T_5 (plantingon 15 January), T_5 and T_1

(plantingon 15 September) in terms of production of healthy cane. Data in Table 4.2.17 also indicated thatthe lowest *C. tumidicostalis* infested cane yield (4.58 t ha^{-1}) was recorded from T_3 (planting on 15 November) having no significant difference with T_6 (5.21 t ha^{-1}) but significantly different from dates. In contrast the highest *C. tumidicostalis* infested cane yield (11.32 t ha^{-1}) in T_1 (planting on 15 September (followed by (9.72 t ha^{-1}) in T_2 (planting on 15 October) having significant difference between them. Thus higher level of infestation occurred at early sowing crops. Further, the maximum total cane yield (88.99 t ha^{-1}) was obtained from T_3 treatment (planting on 15 November) as against the minimum (55.39 t ha^{-1}) from T_6 treatment (planting on 15 February).

The above result indicated that 15 November was the most appropriate for sugarcane plantation among the six planting dates in terms of maximum healthy (insect free) and total cane yield and minimum *C. tumidicostalis* infested cane yield. The order of six planting dates in terms of production of healthy yield is planting on 15 November (T_3)> planting on 15 December (T_4)> planting on 15 October (T_2)> planting on 15 January (T_5)> plantingon 15 September (T_1)> planting on 15 February (T_6). But the order of six planting dates in terms of production of *C. tumidicostalis* infested yield was planting on 15 September (T_1)> planting on 15 October (T_2> planting on 15 December (T_4)> planting on 15 January (T_5)> planting on 15 February (T_6) > planting on 15 November (T_3).

Table 4.2.17 Healthy, infested and total cane yield of sugarcane in 2015 at six planting dates

Treatments	Cane yield (t ha^{-1})		
	Healthy	**Infested**	**Total**
T_1= Plantingon 15 September	58.10 d	11.32 a	69.42 c
T_2= Planting on 15 October	66.50 c	9.72 b	76.22 b
T_3= Planting on 15 November	84.41 a	4.58 d	88.99 a
T_4= Planting on 15 December	71.57 b	7.29 c	78.85 b
T_5 = Plantingon 15 January	61.99 cd	6.59 c	68.58 c
T_6= Planting on 15 February	50.18 e	5.21 d	55.39 d
$S_{\bar{x}}$	**1.164**	**0.3283**	**1.101**
C.V.%	**3.56**	**8.81**	**3.02**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

4.3 Screening and evaluating of some sugarcane varieties against sugarcane stem borer *(Chilo tumidicostalis)* in Bangadesh

4.3.1 Cane infestation by *C. tumidicostalis* in ten tested sugarcane varieties

Remarkable variation was observed in number of healthy, infested and total canes in 10 sugarcane varieties. The result of number of healthy, infested and total canes per plot in 10 sugarcane varieties has been presented in Table 4.3.18. The highest number of healthy canes per plot (564.0) was recorded from Isd 36 variety but have no significant variations with Isd 26 (548.33) but significantly different from other eight varieties. On the other hand, the lowest number of healthy canes per plot (412.7) was recorded form Isd 40 variety, which was significantly lower than all other varieties. However, no significant variation was observed between Isd 26 (548.3 plot^{-1}) and Isd 37 (545.0 plot^{-1}) in respect of number of healthy canes plot^{-1}. Moreover, Isd 37 (545.0 plot^{-1}) and Isd 33 (529.3 plot^{-1}) gave statistically similar result for producing healthy cane per plot. On the other hand, the highest number of infested canes (155.7 plot^{-1}) was recorded from Isd 40, which was significantly higher than all other tested varieties. The lowest number of infested canes (34.67 plot^{-1}) was recorded in Isd 36 having significant different from other varieties. Table 4.3.18 also revealed that the highest number of total canes (598.7 plot^{-1}) was observed in Isd 36 variety, which was significantly different from Isd 39 (575.00) and Isd 40 (568.40) but no significant difference with other seven varieties. The lowest number of canes (568.3 plot^{-1}) was obtained from Isd 40.

The infestation percentage in selected ten commercial sugarcane varieties ranged from 5.79 to 27.39%. The lowest percentage of infestation (5.79 %) was found in Isd 36 variety which was significantly lower than all other varieties. In contrast, the highest percent cane infestation (27.39%) was recorded from Isd 40 variety followed by 21.39% in Isd 39 having significant difference between them. No significant varitation was observed between Isd 26 (7.53%) and Isd 37 (7.99%). Below 10% cane infestation was found only in Isd 36, Isd 26 and Isd 37 although percent infestation was slightly higher in Isd 26 and Isd 37 than Isd 36. Intermediate level of cane infestation by stem borer was observed in Isd 33 (10.28), Isd 20 (10.85), Isd 16 (11.46) Isd 34 (13.67) and Isd 38 (14.67).

Table 4.3.18 Number of healthy, infested and total canes per plot and percent cane infestation by *C. tumidicostalis* in 10 sugarcane varieties

Treatments	Number of canes per plot			Percent cane infestation
	Healthy	Infested	Total	
Isd 16	517.30 de	67.00 d	584.30 abc	11.46 e
Isd 20	523.00 d	63.67 d	586.67 abc	10.85 f
Isd 26	548.33 ab	44.67 e	593.00 ab	7.53 h
Isd 33	529.33 cd	60.67 d	590.00 ab	10.28 g
Isd 34	503.33 ef	79.67 c	583.00 abc	13.67 d
Isd 36	564.00 a	34.67 f	598.67 a	5.79 i
Isd 37	545.00 bc	47.33 e	592.33 ab	7.99 h
Isd 38	496.00 f	85.33 c	581.33 abc	14.67 c
Isd 39	452.00 g	123.00 b	575.00 bc	21.39 b
Isd 40	412.70 h	155.70 a	568.40 c	27.39 a
$S_{\bar{x}}$	**4.28**	**2.34**	**4.17**	**0.26**
CV (%)	**8.46**	**5.38**	**6.23**	**5.10**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

4.3.2. Internodes infestation by *C. tumidicostalis* in ten sugarcane varieties

The number of healthy, infested and total internodes per infested plant in ten sugarcane varieties is shown in Table 4.3.19. The highest number of healthy internodes per plant (24.50) was recorded from Isd 36 having significant variations with others. On the other hand, the lowest number of healthy internodes per plant (17.67) was recorded in Isd 40 which was significantly lower than all other varieties. The highest number of infested internodes per plant (4.90) was recorded from Isd 40, which was significantly higher than all other varieties. The lowest number of infested internodes per plant (2.67) was recorded in Isd 36 having no significant difference with Isd 26 (2.83) but significantly different form other varieties. It was also observed that the highest number of total internodes per plant (27.17) was observed in Isd 36, having significant variation from other varieties as against the lowest (22.57/plant) in Isd 40.

Table 4.3.19 also revealed that the internode infestation per plant by stem borer in selected ten commercial sugarcane varieties ranged from 9.83 to 21.71%. The lowest percentage of internode infestation (9.83%) was found in Isd 36 followed by 10.81% in Isd 26 having no significant difference between them but significantly different from other varieties. In contrast the highest internode infestation per plant (21.71%) was recorded from Isd 40 which was significantly higher than all other varieties. Staistically similar level of internode infestation was recorded from Isd 26 (10.81%) and Isd 37 (11.71%). No significant variation was also observed between Isd 37 (11.71%) and Isd 33 (12.34%) and between Isd 34 (15.99%) and Isd 16 (14.98%) in respect of internode infestation per plant by stem borer.

Table 4.3.19 Number of healthy, infested, total internodes and percent internode infestation by C. *tumidocostalis* in ten sugarcane varieties

Variety	Number of internodes per plant			Percent internode infestation
	Healthy	Infested	Total	
Isd 16	20.27 f	3.57 d	23.83 f	14.98 d
Isd 20	20.90 e	3.20 e	24.10 e	13.28 e
Isd 26	23.33 b	2.83 gh	26.17 b	10.81 gh
Isd 33	21.80 d	3.07 ef	24.87 d	12.34 f
Isd 34	19.60 g	3.73 cd	23.33 g	15.99 d
Isd 36	24.50 a	2.67 h	27.17 a	9.83 h
Isd 37	22.40 c	2.97 fg	25.37 c	11.71 fg
Isd 38	19.40 g	3.87 c	23.27 g	16.63 c
Isd 39	18.73 h	4.23 b	22.97 h	18.42 b
Isd 40	17.67 i	4.90 a	22.57 i	21.71 a
$S_{\bar{x}}$	**0.07**	**0.05**	**0.06**	**0.42**
C.V.%	**0.61**	**2.43**	**0.44**	**3.60**

In a column, means followed by same letter(s) are not significantly different at *p= 0.05* by Duncan Multiple Range Test (DMRT).

4.3.3 Population of *C. tumidicostalis* larva per infested plant in ten sugarcane varieties

The population of stem borer larva per infested plant in selected ten commercial sugarcane varieties ranged from 21.93 to 56.00 (Figure 4.3.44). The lowest number of stem borer larva (21.93/plant) was found in Isd 37 (T_7) having no significant difference with Isd 34 (25.13/plant) and Isd 36 (30.07/plant) but significantly different from other varieties (Figure 4.344). In contrast, the highest number of larva (56.00) was observed in Isd 40 followed by 53.27 plant^{-1}, 48.80 plant^{-1} and 47.73 plant^{-1} in Isd 39, Isd 38 and Isd 20 having no significant difference among them.

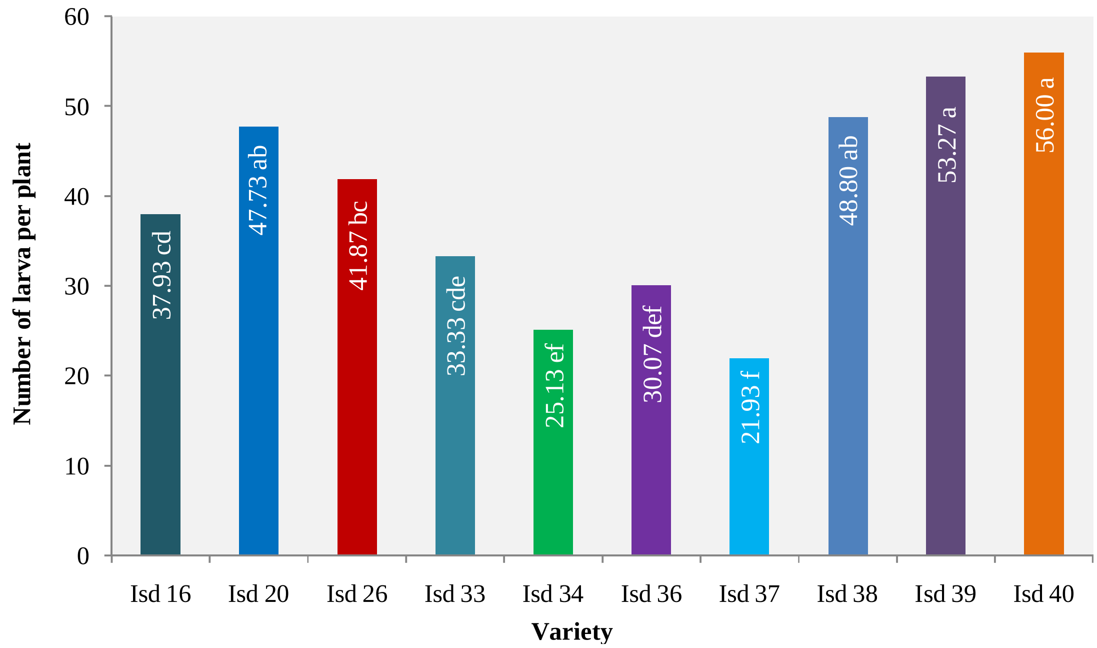


Figure 4.3.44. Number of *C. tumidocostalis* larva per infested plant in 10 sugarcane varieties.

4.3.4 Cane yield of ten sugarcane varieties

The yield of healthy, infested and total canes in ten sugarcane varieties has been presented in Table 4.3.20. The highest yield of healthy cane (79.34 t ha^{-1}) was obtained from Isd 36 followed by 78.60 t ha^{-1} in Isd 37 having no significant difference between them. Isd 33 (71.83 t ha^{-1}), Isd 26(71.69 t ha^{-1}) and Isd 34 (71.45 t ha^{-1}) produced statistically similar healthy cane yield. In contrast, the lowest healthy cane yield (45.83 t ha^{-1}) was obtained from Isd 40 which was significantly lower than other varieties. Isd 40 variety also produced significantly higher quantity of infested cane yield (7.88 t ha^{-1}) and minimum infested cane yield (2.81 t ha^{-1}) was obtained from Isd 36 variety. The total cane yield was found maximum in Isd 37 (82.76 t ha^{-1}) having no significant variation from that of Isd 36 (82.15 t ha^{-1}).

Table 4.3.20 Healthy, infested and total cane yield of ten sugarcane varieties

Variety	Cane yield (t/ha)		
	Healthy	**Infested**	**Total**
Isd 16	68.34 c	4.95 c	73.28 de
Isd 20	67.76 c	4.40 cd	72.16 e
Isd 26	71.69 b	3.27 e	74.96 cd
Isd 33	71.83 b	4.65 cd	76.49 bc
Isd 34	71.45 b	6.68 b	78.12 b
Isd 36	79.34 a	2.81 e	82.15 a
Isd 37	78.60 a	4.16 d	82.76 a
Isd 38	59.99 d	4.95 c	64.94 f
Isd 39	50.75 e	6.38 b	57.13 g
Isd 40	45.83 f	7.88 a	53.71 h
$S_{\bar{x}}$	**0.5672**	**0.1378**	**0.5428**
CV (%)	**1.48**	**4.77**	**1.31**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

The above result indicated that Isd 36 varieties produced the highest number of healthy and total canes per plot and gave the lowest number of stem borer infested canes per plot with minimum percentage of stem borer infestation. This variety also produced the highest amount of healthy and total cane yield compared to other tested varieties. The order of productivity of ten sugarcane vaireties against stem borer was Isd 36 > Isd 26> Isd 37 > Isd 33 > Isd 20> Isd 16 > Isd 34 > Isd 38 > Isd 39 > Isd 40. Chohan *et al.* (2014) reported that comparative performance of 12 sugarcane genotypes. He found that stem borer accounted high infestation followed by top shoot and root borer among the genotypes. The genotypes HoTh-402, HoTh-404, HoTh-408, HoTh-409, HoTh-414 and HoTh-430 were arranged from higher to lower order for their productivity performance and selected for further testing and progression in final selection trials. Abdullah *et al.* (2006) obtained stem borer infestation with a range of 5.25 to 55.21% showing the highest infestation in the clone I 429-99 compared to standard varieties Isd 20 and Isd 32. Islam *et al.* (2016) observed that stem borer infestation ranged from 22.82-35.99% in Isd 37. The stem borer infestation in 6 varieties were observed from 15.23% to 22.0% and 28.70% in CoS 767 which were classed moderately resistant. Only Co 1148 was susceptible (30.10%) to stem borer attack (Pandey *et al.*, 1997). Pandey *et al.* (1997) tested 23 varieties and reported that 16 varieties had 15% infestation ranging from 5.76% in CoS 93422 to 14.88% in CoS 92234. Pandey *et al.* (1994) noted that out of two hundred and forty accessions of sugarcanes, twelve were found resistant against *Chilo tumidicostalis*. Suhartawan (1993) reported that POJ 3061, PS 56 and M 442-51 out of ten varieties of sugarcane were moderately resistant to *Chilo tumidicostalis*. Padmanabhan *et al.* (1990) conducted experiment with 31 sugarcane clones and six standard cultivars for resistance to pests and reported that 31 entries were resistant and 5 moderately resistant and 1 susceptible to *Chilo tumidicostalis*. Thus Isd 36 variety was selected as resistant cultivar for the development of integrated management practices against stem borer.

4.3.5 Morphological features of ten sugarcane varieties and their relationship with stem borer infestation

4.3.5.1 Stem colour and pith of ten sugarcane varieties

Stem color of ten sugarcane varieties has been described in Table 4.3.21. Stem color ten sugarcane varieties was described by BSRI (2010) which was varied such as yellowish green color observed in Isd 33, Isd 34, Isd 37, Isd 38 and Isd 39; greenish yellow in Isd 16 and Isd 26; greenish white in Isd 20; pink in Isd 40 and light green in Isd 36 (Table 4.3.21). The highest stem borer infestation (27.39%) was observed in variety Isd 40 (Table 3.3.20) which was pink coloured. On the other hand lowest stem borer infestation (5.79%)

was found in Isd 36 variety which was light green coloured. Moreover, 7.53% and 7.99% infestation was found in Isd 26 and Isd 37 which were greenish yellow coloured. Thus sugarcane varity with greenish colour had less infestation than pink or yellow colour stem. Sugarcane variety with greenish color may inhibit stem borer infestation.

Pith or pipe was also observed in sugarcane varieties Isd 16, Isd 20, Isd 26, Isd 34, Isd 36, Isd 37; but the variety Isd 33, Isd 38, Isd 39 and Isd 40 were free from pith (Figure 3.3.11). Pith or pipe is more or less hollow area of the sugarcane stems which contain less fiber. Higher stem borer infested variety (27.39%) Isd 40 had no pith. Furthrer lower stem borer infested variety Isd 36 also had no pith. So it was very difficult to relate stem borer infestation with pith characteristics of sugarcane varieties.

Table 4.3.21 Stem color and pith of the tested ten sugarcane varieties

Variety	**Stem color**	**Presence or absence of pith in stem (pipe)**
Isd 16	Greenish yellow with yellow, become reddish color when exposed to sunlight	Present
Isd 20	Greenish white, become black or pink color when exposed to sunlight	Present
Isd 26	Greenish yellow with yellow, become reddish color when exposed to sunlight	Present
Isd 33	Yellowish green	Absent
Isd 34	Yellowish green	Present (prominent)
Isd 36	Light green, become greenish pink when exposed to sunlight	Present
Isd 37	Yellowish green, become greenish yellow when exposed to sunlight	Slightly present/present
Isd 38	Yellowish green	Absent
Isd 39	Yellowish green	Slightly present/absent
Isd 40	Pinkish color	Absent

4.3.5.2 Length of leaf sheath and leaf blade, fiber content of ten tested sugarcane varieties and its effect on stem borer infestation

The length of leaf sheath varied from 2.33 cm to 3.67 cm in ten sugarcane varieties (Table 4.3.22). The highest length of leaf sheath (3.67 cm) was recorded from Isd 39 which was significantly higher than other tested varieties. But the lowest length of leaf sheath (2.33 cm) was observed in Isd 38, having no significant difference from Isd 34 (2.77 cm) and Isd 36 (2.83 cm). Length of leaf blade in ten sugarcane varieties varied from 48.77 to 52.00 cm. The highest length of leaf blade (52.00 cm) was recorded from Isd 36 which was significantly higher than other nine sugarcane varieties. In contrast, the lowest (48.77 cm) length of leaf blade was observed from Isd 40 having no significant variation with other varieties except Isd 36 (Table 4.3.22).

Data also indicated that fiber content in the stem of ten sugarcane varieties varied from 14.00 to 16.25%. The highest percent fiber (16.25%) was observed in Isd 36 having significant variation with other varieties (Table 4.3.22). In contrast the lowest percent fiber (14.00%) was observed in Isd 40 and it was not significantly different from that of Isd 39 (14.07%). Similar level of fiber was present in Isd 33 (15.87%) and Isd 26 (15.83%). No significant variation was also observed among Isd 37 (15.35%), Isd 20 (15.30) and Isd 16 (15.27%) in respect of fiber content. This result was almost similar to with the findings of Rahman (2013) who observed 14.38% fiber in Isd 38 and no significant variation between Isd 38 and Isd 40 in fiber content.

Table 4.3.22 Length of leaf sheath and leaf blade and fiber content of the stem in ten tested sugarcane varieties

Variety	Length of leaf sheath (cm)	Length of leaf blade (cm)	Percent fiber (%)
Isd 16	2.90 b	49.50 b	15.27 c
Isd 20	3.00 b	49.03 b	15.30 c
Isd 26	2.93 b	50.27 b	15.83 b
Isd 33	3.13 b	50.07 b	15.87 b
Isd 34	2.77 bc	49.30 b	14.13 e
Isd 36	2.83 bc	52.00 a	16.25 a
Isd 37	3.13 b	50.00 b	15.35 c
Isd 38	2.33 c	49.23 b	14.62 d
Isd 39	3.67 a	48.97 b	14.07 e
Isd 40	2.93 b	48.77 b	14.00 e
$S_{\bar{x}}$	**0.1225**	**0.4223**	**0.04472**
C.V.%	**7.13**	**1.47**	**0.53**

In a column, means followed by same letter(s) are not significantly different at *p= 0.05* by Duncan Multiple Range Test (DMRT).

4.3.5.3 Relationship of *C. tumidocostalis* infestation with leaf sheath, length of leaf blade and fiber content of the stem

The relationship between stem borer infestation and length of leaf sheath was shown in Figure 4.3.45 (C). A negative linear relationship was observed between sugarcane stem borer infestation and length of leaf sheath of sugarcane. The regression equation y= a + bx, where y= plant infestation, a= 0.240, b= 5.042 and x= leaf sheath length. This suggests that stem borer infestation is dependent on stem covered by leaf sheath and more than 4% (R^2=0.043) of variation in the stem borer infestation can be explained by the variation of stem covered by leaf sheath. So, it indicated that the stem borer infestation decreased with the increase of leaf sheath of the sugarcane variety.

Similarly negative linear relationship was observed between sugarcane stem borer infestation and length of leaf blade [Figure 4.3.45 (D)]. The regression equation y= a + bx, where y= plant infestation, a= 326.3, b= 6.268 and x= length of leaf blade. This suggests that stem borer infestation is dependent on length of leaf blade and more than 54% (R^2=0.540) of variation in the stem borer infestation can be explained by the variation of length of leaf blade. So, it indicated that the stem borer infestation decreased with the increased of length of leaf blade.

Further, negative linear relationship was observed between sugarcane stem borer infestation and fiber percent of cane [Figure 4.3.45 (E)]. The regression equation y= a + bx, where y= plant infestation, a= 144.5, b= 8.62 and x= fiber percent of cane. This suggested that stem borer infestation is dependent on the fiber percent of cane and more than 76% (R^2=0.759) of variation in the stem borer infestation can be explained by the variation of fiber percent of cane. So, it indicated that the stem borer infestation decreased with the increased of fiber percent of cane in the stem.

Leaf sheath covers some part of the sugarcane stem; long leaf sheath may cover lager part of the stem and inhibit stem borer infestation. Morerover, long leaf blade may hinder the activity of stem borer and reduce infestation. The result agrees with the finding of Rahman (2013) who reported that minimum infestation of stem borer was observed in the varieties where fiber percentage was higher.

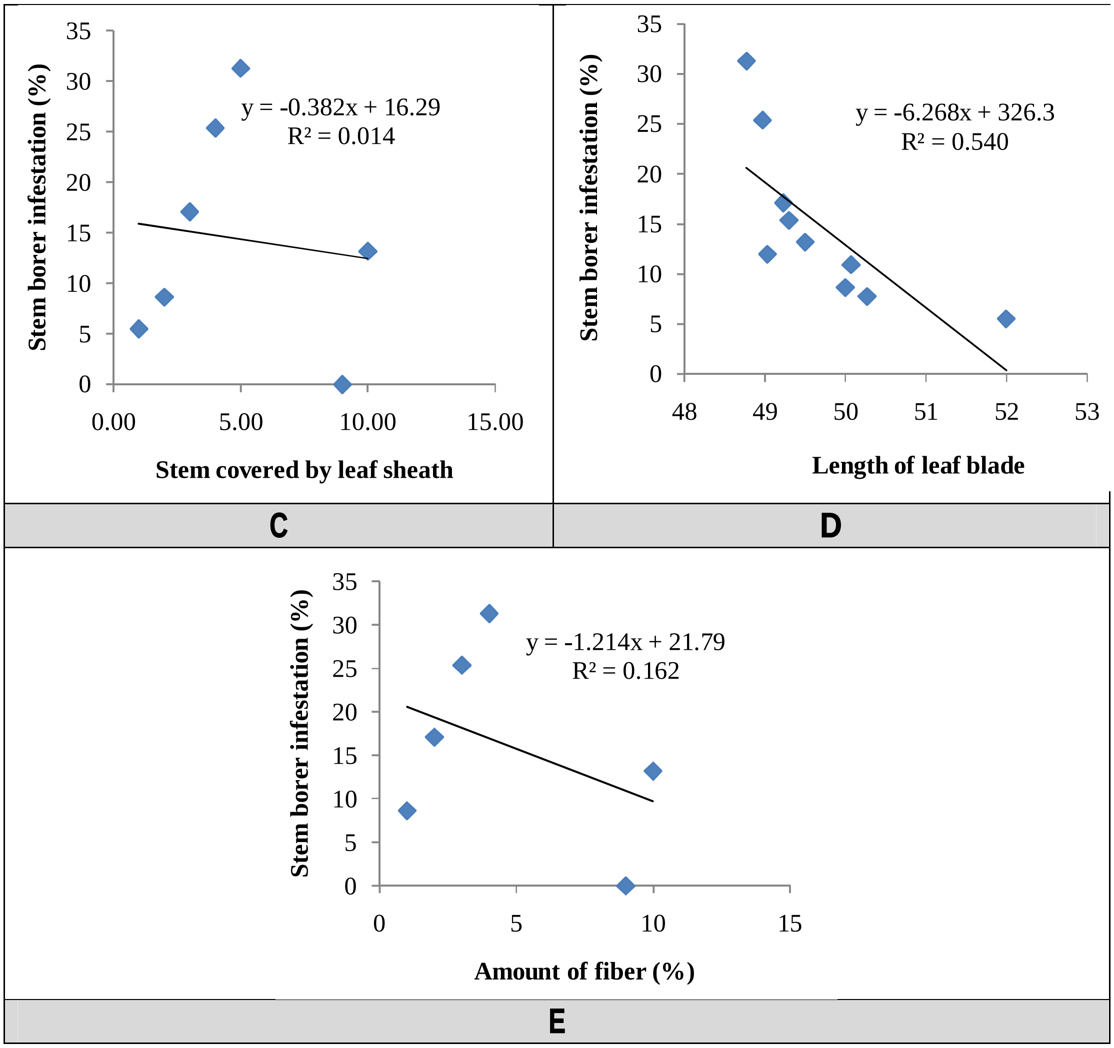


Figure 4.3.45: Relationship of stem borer infestation with (C) length of leaf sheath, (D) leaf blade and (E) percent fiber in cane.

4.3.6 Brix percent, pol percent cane and reducing sugar of ten sugarcane varieties and their relationship with stem borer infestation

The brix in ten selected commercial sugarcane varieties ranged from 15.57 to 17.17% (Table 4.3.23). The highest brix percent (17.17%) was recorded from Isd 36 followed by Isd 16 (16.83) having no significant statistical variation between them. In contrast, the lowest brix percent (15.57%) was obtained from Isd 40 having no significant variation with Isd 39 (15.80%). The pol percent cane varied from 9.36% to 10.26% in 10 sugarcane varieties (Table 4.3.23). The highest pol percent cane (10.26%) was obtained from Isd 36 having no significant difference with that of Isd 26 (10.23%), Isd 37 (10.21%), Isd 33 (10.14%), Isd 20 (10.05%) and Isd 16 (9.98%). The lowest pol percent cane (9.36%) was recorded from Isd 39 and Isd 40 having no significant variation with Isd 34 (9.41%) and Isd 38 (9.61%). The percent reducing sugar also varied from 0.81% to 01.26% in ten sugarcane varieties. The highest (1.26%) percent reducing sugar was observed from Isd 36 followed by Isd 26 and Isd 37. The lowest (0.81%) percent reducing sugar was observed from both Isd 39 and Isd 40, having significant variation from other varieties (Table 4.3.23).

Table 4.3.23. Brix percent, Pol percent cane and percent reducing sugar in ten sugarcane varieties

Variety	Brix percentage	Pol percent cane	Percent reducing sugar
Isd 16	16.83 ab	9.98 ab	0.99 d
Isd 20	16.03 cd	10.05 a	1.12 bc
Isd 26	16.73 b	10.23 a	1.21 a
Isd 33	16.77 b	10.14 a	1.09 c
Isd 34	16.00 cd	9.41 c	1.09 c
Isd 36	17.17 a	10.26 a	1.26 a
Isd 37	16.30 c	10.21 a	1.20 ab
Isd 38	16.00 cd	9.61 bc	1.11 c
Isd 39	15.80 de	9.36 c	0.81 e
Isd 40	15.57 e	9.36 c	0.81 e
$S_{\bar{x}}$	**0.08563**	**0.097**	**0.018**
CV %	**0.91**	**1.69**	**3.55**

In a column, means followed by same letter(s) are not significantly different at *p= 0.05* by Duncan Multiple Range Test (DMRT).

(T_1= Isd 16, T_2= Isd 20, T_3= Isd 26, T_4= Isd 33, T_5 = Isd 34, T_6= Isd 36, T_7= Isd 37, T_8=Isd 38, T_9=Isd 39 and T_{10}= Isd 40).

4.3.7 Relationship of *C. tumidocostalis* infestation with reducing sugar and fiber content of sugarcane

The relationship between stem borer infestations with brix percent, pol percent cane and reducing sugar was shown in Figure 4.3.46. A negative linear relationship was observed between sugarcane stem borer infestation and brix percent of ten sugarcane varieties [Figure 4.3.46 (F)]. The regression equation y= a + bx, where y= plant infestation, a= 206.1, b= 11.73 and x= brix percentage. This suggested that stem borer infestation is dependent on the brix and more than 57% (R^2=0.574) of variation in the stem borer infestation can be explained by the variation of brix. So, it indicated that the stem borer infestation decreased with the increased brix in stem.

Similarly, negative linear relationship was observed between sugarcane stem borer infestation and pol percent cane of ten sugarcane varieties [Figure 4.3.46 (G)]. The regression equation y= a + bx, where y= plant infestation, a= 199.8, b= 18.77 and x= pol percent cane. This suggested that stem borer infestation is dependent on the pol percent cane and more than 79% (R^2=0.785) of variation in the stem borer infestation can be explained by the variation of pol percent cane. So, it indicated that the stem borer infestation decreased with the increased pol percent cane in stem.

Negative linear relationship was also observed between sugarcane stem borer infestation and reducing sugar content of ten sugarcane varieties [Figure 4.3.46(H)]. The regression equation y= a + bx, where y= plant infestation, a= 66.26, b= 48.28 and x= reducing sugar. This suggested that stem borer infestation is dependent on the reducing sugar and more than 87% (R^2=0.867) of variation in the stem borer infestation can be explained by the variation of reducing sugar. So, it indicated that the stem borer infestation decreased with the increased reducing sugar in stem.

Positive correlation was found between pol percent cane and percent reducing sugar (Ahmed and Khan, 1991; Rahman and Alam, 1987; Kumar *et al.*, 1972). Rahman (2013) found that positive correlation with pol percent cane but negatively correlated with percent reducing sugar in cane. The lowest reducing sugar is desired for sugarcane production under commercial field condition (Chen, 1985 and Beniwal *et al*., 1989). They observed that reducing sugar was minimum (10.92%) in resistant clone Co7314 and maximum (89.33%) in highly susceptible clone S 78/560. Percent infestation of sugarcane borer was negatively correlated with the Brix percent and percent fiber in cane during infestation period. Positive correlation was found with percent total sugar and percent fiber in cane (Ahmed and Khan, 1991; Rahman and Alam, 1987; Kumar *et al.*, 1972). Rahman (2013) found that positive correlation with percent total sugar but negative correlation with percent fiber in cane.

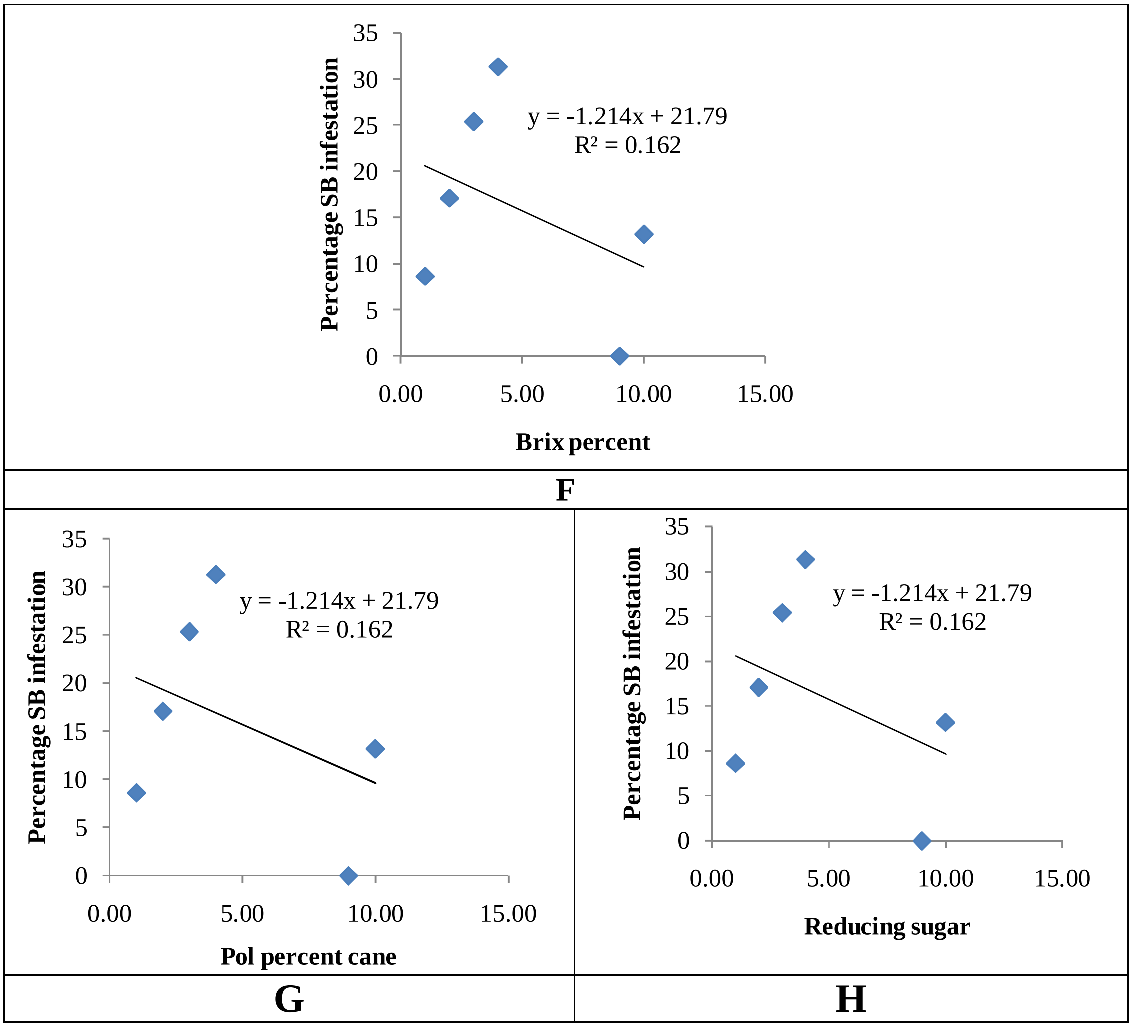


Figure 4.3.46. Relationship of *C. tumidocostalis* infestation with (F) Brix percent (G) Pol percent cane and (H) Reducing sugar

4.3.8 Nitrogen, phosphorus, potasium and silicon content of ten sugarcane varieties and its relationship with stem borer infestation

4.3.8.1 Nitrogen, phosphorus, potasium and silicon content of ten sugarcane varieties

The relationship between nitrogen cotent of sugarcane varieties and incidence of stem borer infestation ranged from 0.81% to 1.16% (Table 4.3.24). The highest amount of nitrogen (1.16%) was obtained from Isd 36 variety which was significantly higher than the other nine varieties. The lowest (0.81%) quantity of nitrogen was recorded from Isd 40 having no significant differcnce with Isd 38 (0.82%), Isd 39 (0.83%), Isd 34 (10.86%) and Isd 16 (0.88%). The amount phosphorus in selected ten sugarcane varieties ranged from 0.06% to 0.13% but no significant difference was found among them. However, the highest amount of phosphorus (0.13%) was obtained from Isd 36 which was closely followed by Isd 26 (0.12%) and Isd 37 (0.11%). In contrast the lowest amount of phosphorus (0.06%) was observed from Isd 40 which was very close to Isd 38 and Isd 39 (0.07%). But the amount of potassium was significantly varied in ten sugarcane varities. The highest amount of potassium (0.79%) was obtained from Isd 36 having significant difference with other varieties. On the other hand, the lowest amount of phosphorous (0.54%) was obtained from Isd 40 having no significant difference with Isd 38 (0.57%), Isd 39 (0.60%), Isd 20 (0.60%) and Isd 16 (0.61%). Silicon content in ten varities greatly and ranged from 3.65 ppm to 22.47 ppm. Table 4.3.24 demonstrated that the highest amount of silicon (22.47 ppm) was obtained from Isd 36 which was significantly higher than all other nine varieties followed by 19.87 and 16.48 ppm in Isd 26 and Isd 37. In contrast the lowest amount of silicon (3.65 ppm) was obtained from Isd 40 having no significant variation with Isd 39 (4.07 ppm). Almost similar amount of silicon was recorded from Isd 38 (5.04 ppm) and Isd 34 (5.08 ppm), Isd 16 (8.51 ppm), Isd 20 (8.60).

Table 4.3.24 Nitrogen, phosphorus, potassium and silicon contents in infested cane of 10 sugarcane varieties during peak infestation of stem borer

Variety	Nitrogen, phosphorus, potassium and silicon content in infested cane			
	Nitrogen (%)	**Phosphorus (%)**	**Potassium (%)**	**Silicon (ppm)**
Isd 16	0.88 c	0.09	0.61 cde	8.51 e
Isd 20	1.06 b	0.08	0.60 cde	8.60 e
Isd 26	1.06 b	0.12	0.71 b	19.87 b
Isd 33	1.00 b	0.10	0.67 bc	14.42 d
Isd 34	0.86 c	0.08	0.63 bcd	5.08 f
Isd 36	1.16 a	0.13	0.79 a	22.47 a
Isd 37	1.02 b	0.11	0.70 b	16.48 c
Isd 38	0.82 c	0.07	0.57 de	5.04 f
Isd 39	0.83 c	0.07	0.60 cde	4.07 g
Isd 40	0.81 c	0.06	0.54 e	3.65 g
$S_{\bar{x}}$	**0.01826**	**NS**	**0.01826**	**0.2258**
CV (%)	**1.86**		**2.82**	**3.61**

In a column, means followed by same letter(s) are not significantly different at *p= 0.05* by Duncan Multiple Range Test (DMRT).

4.3.8.2 Relationship between stem borer infestation and nitrogen, phosphorus, potasium and silicon content of ten tested sugarcane varieties

The relationship between stem borer infestation and nitrogen percent in infested cane was computed and presented in Figure 4.3.47 (I). A negative linear relationship was observed between sugarcane stem borer infestation and quantity of nitrogen in ten sugarcane varieties. The regression equation y= a + bx, where y= plant infestation, a= 65.61, b= 53.59 and x= nitrogen percent in infested cane. This suggested that stem borer infestation is dependent on nitrogen percent in infested cane and more than 68% (R^2=0.680) of variation in the stem borer infestation can be explained by the variation of nitrogen percent in infested cane. So, it indicates that the stem borer infestation decreased with the increased nitrogen percent in infested cane.

Similarly negative linear relationship was observed between sugarcane stem borer infestation and quantity of phosphorus in ten sugarcane varieties [Figure 4.3.47 (J)]. The regression equation y= a + bx, where y= plant infestation, a= 41.63, b= 294.9 and x= phosphorus percent in infested cane. This suggested that stem borer infestation is dependent on phosphorus percent in infested cane and more than 73% (R^2=0.734) of variation in the stem borer infestation can be explained by the variation of phosphorus percent in infested cane. So, it indicated that the stem borer infestation decreased with the increased phosphorus percent in infested cane.

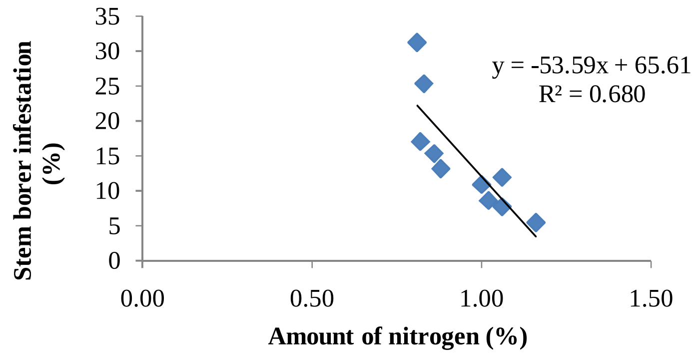
A negative linear relationship was observed between sugarcane stem borer infestation and quantity of potassium in ten sugarcane varieties [Figure 4.3.47(K)]. The regression equation y= a + bx, where y= plant infestation, a= 72.09, b= 89.34 and x= potassium percent in infested cane. This suggested that stem borer infestation is dependent on potassium percent in infested cane and more than 68% (R^2=0.681) of variation in the stem borer infestation can be explained by the variation of potassium percentage in infested cane. So, it indicated that the stem borer infestation decreased with the increased potassium percent in infested cane.

The relationship between stem borer infestation and presence of silicon (ppm) was computed in Figure 4.3.47 (L). A negative linear trend was observed between sugarcane stem borer infestation and quantity of silicon in ten sugarcane varieties. The regression equation y= a +bx, where y= plant infestation, a= 25.04, b= 0.956 and x= silicon. This suggested that stem borer infestation is dependent on the silicon and more than 68%

(R^2=0.676) of variation in the stem borer infestation can be explained by the variation of silicon. So, it indicated that the stem borer infestation decreased with the increased silicon in stem.

Findings of the present study revealed that infestation of sugarcane stem borer were negatively correlated with total nitrogen, phosphorus, potassium and silicon content of infested sugarcane stem. Similar finding was recorded for potassium content in sugarcane leaves (Rahman, 2013). But positive correlation was reported for nitrogen and phosphorus, in sugarcane leaves (Wood, 1984; Abayomi, 1987; Rahman *et al*., 1992; Banger *et al*., 1994). Saikia *et al*. (1994) reported no significant effect of nitrogen levels on the incidence of *C. tumidicostalis*. The presences of different nutrient elements in sugarcane leaves influence stem borer infestations (Afolobi, 1988; Bokhtiar and Sakurai, 2003 and Dang *et al.*, 1995). Liang *et al.* (2015) reported that silicon (Si) is involved in plant resistance against insect pest damage. Deposition of silica in plant epidermal cells provides a physical barrier against insect's probing and feeding or mouth parts penetration into plant tissues (Djamin and Pathak, 1967; Kvedaras, 2007).

The protective effect of silica to plants against insect herbivores is related to the level of its accumulation and polymerization in plant tissues with highest levels and positively being correlated with increased resistance (Juma *et al*., 2015; Laing *et al*. 2006; Bélanger *et al*., 2003). Silicon depositions may provide a mechanical barrier against insect pests. Applications of Si also appear to reduce insect activity on crops. This suppression includes pests such as stem borer (Savant *et al*.1997). Vasanthi *et al*. (2014) mentioned that the role of silicon in pest control and a higher silica content reduced the incidence of sugarcane shoot borer; stem borer; African stalk borer. Silica mediated stem borer resistance on sugarcane has been partly associated with delayed stalk penetration by larvae as a result of leaf and stalk silification (Djamin and Pathak, 1967; Kvedaras, 2007). Silicon treatment significantly decreased borer penetration, stalk damage, and larval mass gain. The results are consistent with the hypothesis that Si contributes to sugarcane stalk borer resistance by impeding larval penetration (Kvedaras and Keeping, 2007).



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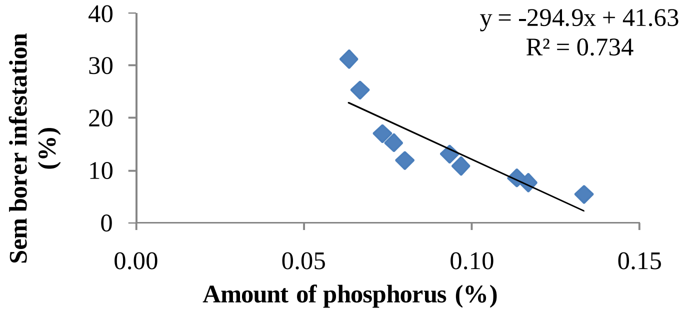

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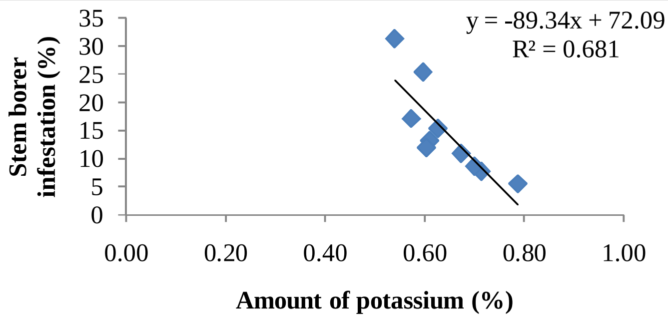

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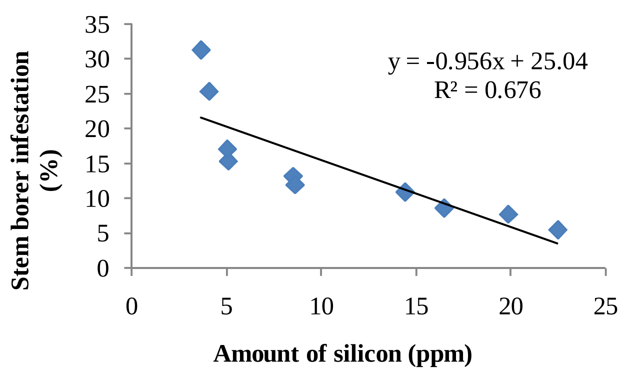

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Figure 4.3.47: Relationship of stem borer infestation with (I) nitrogen, (J) phosphorus, (K) potassium and (L) silicon content in ten sugarcane varieties.

4.4 Evaluation of some chemical insecticides against sugarcane stem borer in field

4.4.1 Effect of different chemical insecticides on stem infestation by *C. tumidicostalis*

4.4.1.1. Effect on stem infestation

The effect of different treatments on sugarcane stem borer was evaluated during stem formation. Significant variation was observed for number of healthy, infested and total canes in different treatments. Results presented in Table 4.4.25 indicated that the highest number of healthy canes per plot (261.80) was recorded from T_5 treatment (Nokotap 6G @ 50 kg ha^{-1}) having significant statistical variations with others. On the other hand, the lowest number of healthy canes per plot (200.00) was recorded in T_6 (untreated control treatment), which was significantly lower than all other treated plots. Moreover, no significant variation was observed among T_4 (248.0 $plot^{-1}$), T_1 (244 $plot^{-1}$) and T_3 (237.3 $plot^{-1}$) in respect of number of healthy canes/plot. Similarly, the highest number of infested canes (56.75 $plot^{-1}$) was recorded from T_6 treatment (untreated control plot), which was significantly higher than all other treated plots. In contrast, the lowest number of infested canes (12.75 $plot^{-1}$) was recorded in T_5 (Nokotap 6G @ 50 kg ha^{-1}) treated plot having significant difference with other treatments. Moreover, Table 4.4.25 also revealed that the highest number of total canes (274.5 $plot^{-1}$) was observed in T_5 treated plot and which was followed by T_1 (267.80) and T_4 (264.00) treated plots, respectively having no significant variation among them. The lowest number of canes (256.8 $plot^{-1}$) was obtained from T_6 treatment (untreated control plot) without any significant difference with T_1, T_2, T_3 and T_4 treatments but significantly varied with that of T_5 treated plots.

Table 4.4.25. Number of healthy, infested and total canes per plot under different treatments in 2014

Treatments	Number of canes/plot		
	Healthy	**Infested**	**Total**
T_1	244.5 bc	23.25 b	267.8 ab
T_2	234.0 c	25.25 b	259.3 b
T_3	237.3 bc	19.25 c	256.5 b
T_4	248.0 b	16.00 d	264.0 ab
T_5	261.8 a	12.75 e	274.5 a
T_6	200.0 d	56.75 a	256.8 b
S_x	**2.52**	**0.49**	**2.77**
C.V.%	**2.13**	**3.87**	**2.10**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated control].

The effect of different chemicals on percent plant infestation of sugarcane by *C. tumidicostalis* and percent reduction of infestation over untreated control has been presented in Figure 4.4.48. The lowest percentage of infestation (4.51 %) was found in the plots treated with Nokotap 6G @ 50 kg ha^{-1} (T_5) which was significantly different from all other treatments which was followed T_4 (6.04%), T_3 (7.53%), T_1(8.67%) and T_2(9.86%) treated plots. The highest plant infestation (22.01%) was observed in the untreated control plot (T_6) which was significantly higher than all other chemical treatments. Considering percent reduction of *C. tumidicostalis* over untreated control, T_5 also gave the best result by reducing 79.53% cane infestation over control which was significantly higher than all other treatments. Treatment T_2 showed the lowest effectiveness against *C. tumidicostalis* by providing only 55.19% reduction of infestation over untreated control plots. Among the other treatments, T_4 reduced 72.54% infestation of *C. tumidicostalis* over untreated control followed by T_3 (65.79%) and T_1 (60.62%).

The above result on the effectiveness of chemical insecticides on production of healthy cane and percent reduction of stem borer infested canes indicated that T_5 (Nokotap 6G @ 50 kg ha^{-1}) was the most effective treatment against stem borer attacks on sugarcane. This treatment (T_5) gave maximum number of healthy canes per plot (261.8) and reduced 79.53% borer infestation on sugarcane over to untreated control. Treatments T_3, T_4 and T_1 also reduced more than 60% of borer infestation over untreated control and T_2 gave 55.19% reduction of infestation. The order of effectiveness of five chemical insecticides against borer infestation on sugarcane was $T_5 > T_4 > T_3 > T_1 > T_2$.

The findings of the present study are comparable to findings of other researchers. Rahman (2013) used insecticides Seda 50SP @ 3.0 kg ai ha^{-1}, Padan 50SP @ 3.0 kg ai ha^{-1}, Cidan 4G @ 3.0 kg ai ha^{-1}, Razex 4G @ 3.0 kg ai ha^{-1}, Forwatap 4G @ 3.0 kg ai ha^{-1}, Sundan 4G @ 3.0 kg ai ha^{-1}, Padan 4G @ 3.0 kg ai ha^{-1} against sugarcane stem borer. Promising control of stem borer in July and same trend was also observed in August and October with more than 80% infestation reduction over control except in Seda 50SP and Padan 50SP.

Cidan 4G, Razex 4G, Forwatap 4G and Sundan 4G @ 3.0 kg a.i. ha^{-1} applied in June, July and August effectively controlled stem borer of sugarcane. An increase of 28.86 to 50.61% in yield was recorded in insecticide treated plots as compared to untreated ones (Abdullah *et al.,* 2005). Cidan 4G showed more than 80% effectiveness over control against stem borer infestation (Abdullah *et al.,* 2005).

Alam *et al*. (2005) reported that Cidan 4G, Razex 4G, Forwatap 4G and Sundan 4G @ 3.0 kg a.i. ha^{-1} applied in June, July and August effectively controlled stem borer of sugarcane.

Furadan 3G (carbofuran) at 12 kg/ac proved superior in checking stem borer infestation over padan 4G (cartap), basudin 10G (diazinon) and thimet 5G (phorate) (Talpur *et al*., 2002). Shajahan *et al*., (1983) observed that cartap group of insecticide provided effective control of the stem borer pest.

Sugarcane stem borer is an internal feeder and completes its larval and pupal stages inside the cane. It damages sugarcane only in larval stage. Insecticide use as spray on the leaves and stem hence, toxic action of the insecticide does not reach to the target pest and fail to kill the insect. Cartap groups of insecticide control stem borer satisfactorily (Shajahan, *et al*., 1983; Rahman, M.A., 2013). Munir *et al*. (2011) noted that carbofuran 3G granular application reduced borer infestation significantly. Shajahan *et al*, (1983) reported that padan 4G (under cartap group) gave promising results in controlling stem borer. Rana *et al*. (1992) found that Furadan 3G and Curater 3G @ 4.86 kg ha-1 reduced average stem borer infestation to 3.00 to 3.11% but also increased the cane yield up to 11.67 -11.83 tons ha^{-1}. Ishtiaq (2005) opined that granular insecticide was the most promising treatment against the sugarcane borer complex

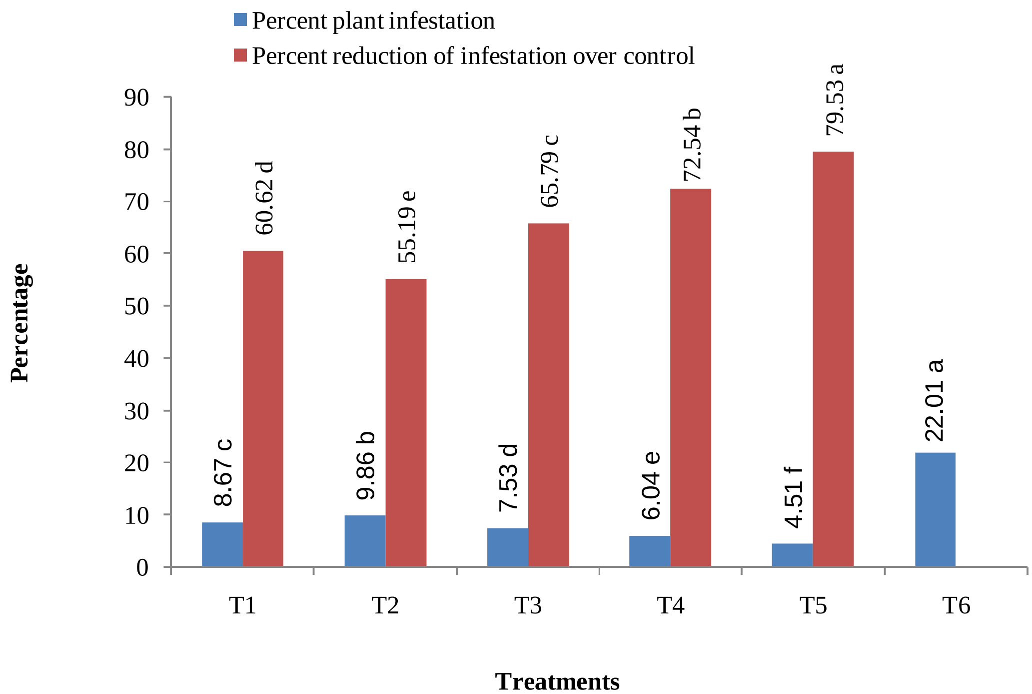

Figure 4.4.48. Effect of different treatments on sugarcane stem infestation by *C. tumidicostalis* and percent reduction of infestation over untreated control in 2014.

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

4.4.1.2. Effect of different chemical insecticides on internodes infestation per infested plant

A remarkable variation was found in number of healthy, infested and total internodes/plants in different treatments. The number of healthy, infested and total internodes/plants per plot treated with different doses was shown in Table 4.4.26. The highest number of healthy internodes/plant (13.44) was recorded from T_5 treatment (Nokotap 6G @ 50 kg ha^{-1}) having statistically significant variations with others. On the other hand, the lowest number of healthy internodes/plant (5.92) was recorded in untreated control (T_6), which was significantly lower than all other treated plots. In contrast, the highest number of infested internodes/plant (5.48) was recorded from untreated control plot, which was significantly higher than all other treated plots. The lowest number of infested internodes/plant (1.98) was recorded in T_5 (Nokotap 6G @ 50 kg ha^{-1}) having significantly lower than other treatments. Table 4.4.26 also expressed that the highest number of total internodes/plant (15.43) was observed in T_5 treated plot. The lowest number of total internodes/plant (11.40) was obtained from untreated control plot having significant difference among the other treated plots.

Table 4.4.26. Number of total, healthy and infested internodes of sugarcane under different treatments during the period from January 2014 to December 2014

Treatments	Number of internodes/plant		
	Healthy	**Infested**	**Total**
T_1	10.08 d	3.27 bc	13.35 d
T_2	9.20 e	3.53 b	12.73 e
T_3	10.87 c	2.80 cd	13.68 c
T_4	11.94 b	2.49 d	14.43 b
T_5	13.44 a	1.98 e	15.43 a
T_6	5.92 f	5.48 a	11.40 f
$S_{\bar{x}}$	**0.11**	**0.11**	**0.05**
C.V.%	**2.22**	**6.94**	**0.73**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

The effect of different chemicals on percent internodes per infested plant was presented in Figure 4.4.49. The lowest percent of internodes infestation per plant (12.85%) was recorded from T_5 treatment (Nokotap 6G @ 50 kg ha^{-1}) having significant variations with others. T_4 (17.22%) and T_3 (20.48%) treatments performed better which were significantly different from T_1 (24.48%) and T_2 (27.70%) treatments. In contrast, the highest percent of

(48.06%) internodes/plant was observed in T_6 (untreated control treatment) which was significantly different from all other treatments.

The above result on the effectiveness of chemical insecticides on percent infested internodes/plant and percent reduction of infested internodes/plant indicated that T_5 (12.85) was the most effective treatment against stem borer attacks on internodes of sugarcane. This treatment (T5) gave maximum number of healthy internodes/plant (13.44) in each plot and reduced 73.21% infested internodes/plant of sugarcane control. Treatments T_4 and T_3 also reduced more than 57% reduction of infested internodes/plant over control. T_1 and T_2 gave only 48.86% and 42.17% reduction of infested internodes per plant, respectively which was significantly lower than other chemical treatments (Appendix 4.4.18). The order of effectiveness of five chemical insecticides against internodes infestation per plant by stem borer on sugarcane was $T_5 > T_4 > T_3 > T_1 > T_2$.

The positive effect of chemical insecticides on sugarcane stem borer have been reported by several authors. The result supports the findings of Talpur *et al.* (2002) who revealed that the application of Padan 4G (cartap) at 9 kg/ac against sugarcane stem borer in respect of cane infestation. It is also agree with the finding of Miah *et al*. (1983) who observed that application of granules of cartap (Padan) at 3 kg a.i./ha gave satisfactory control of the stem borer. Schaff (1975) reported in Jamaica that borer internodes produced 45% less sugar than undamaged internodes and the borer caused variable damage to the sugarcane crop. Humbert (1976) showed average loss of 300 gms sugar per metric ton of cane for every 1% infestation of internodes, this combined with loss of nearly 1500 tons from 900000 tons of cane.

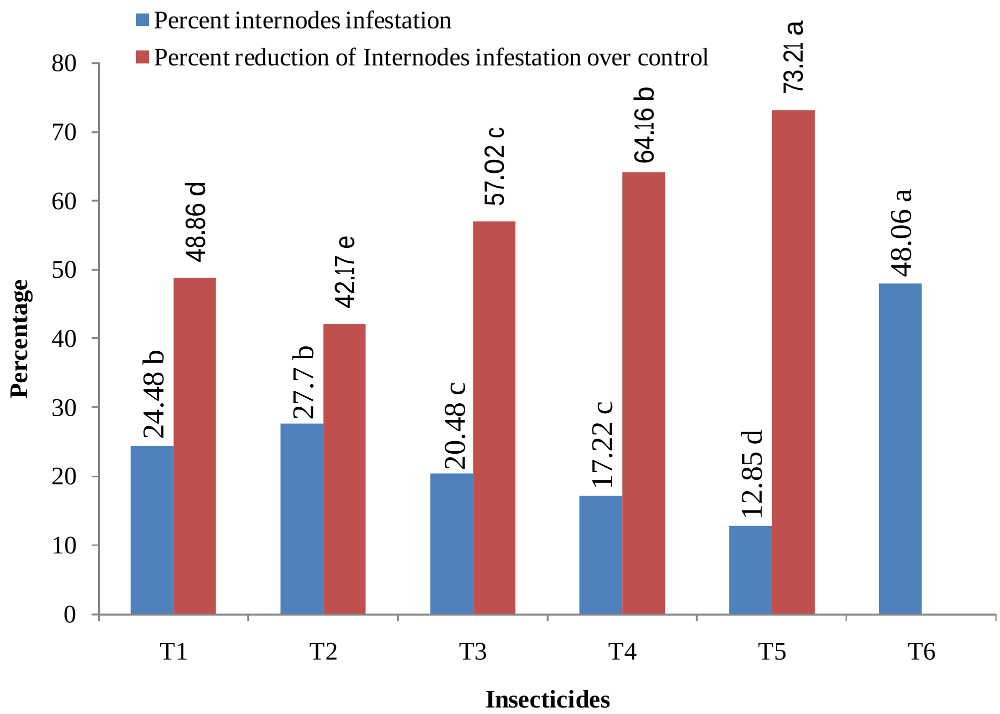

Figure 4.4.49. Effect of different treatments on percent internode infestation per plant by stem borer.

4.4.1.3 Population of larva per infested plant

The effect of different chemicals on the population of stem borer larva in sugarcane was presented in Table 4.4.27. The lowest population of stem borer larva (12.60) was found in T_5 treatment (Nokotap 6G @ 50 kg ha^{-1}) having significant variations with others. The highest number of stem borer larva/plant (49.4) was observed in untreated control plot. The moderate number of stem borer larva per infested plant was recorded in T_3 (19.40) and T_4 (17.24) treatments, respectively. Table 4.4.27 also indicated that the highest percent of reduction of larvae per infested cane (48.06 %) was observed in untreated control plot and showed the highest number of larva/plant as well as highest % internodes/ infested plant and was statistically different from all other treatments. Second highest (27.80) number of larva per plant and % internodes/ infested plant (27.70) recorded in T2. T5 treatment showed the lowest number of larva/plant (12.60) and also lowest %

internodes/infested plant (12.60). In June to August the population consisted of larger instars larvae (Alam *et al*., 2005).

Table 4.4.27. Effect of different treatments on percent of larva/infested plant due to sugarcane stem borer during the period from January 2014 to December 2014

Treatments	Number of larva/plant	Percent reduction of number of larva/infested plant over control
T_1	23.60 c	55.17 d
T_2	27.80 b	47.18 e
T_3	19.40 d	63.14 c
T_4	17.24 d	68.86 b
T_5	12.60 e	80.34 a
T_6	49.40 a	-
$S_{\bar{x}}$	**0.75**	**1.15**
CV (%)	**6.03**	**3.65**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

The above result on the effectiveness of chemical insecticides on the population of stem borer larva and percent reduction of population of stem borer larva over control indicated that T_5 (12.85) was the most effective treatment against stem borer larva in internodes per infested plant of sugarcane. This treatment (T5) showed minimum number of larva on internodes per plant (12.60) in each plot and reduced 80.34% presence of larva on internodes per plant of sugarcane over untreated control (T_6). Treatments $T_{4,}$ T_3 and T_1 reduced more than 55% of larva on internodes per infested plant over untreated control. T_2 gave only 47.18% reduction of larva in internodes per plant over control which was significantly lower than others chemical treatments. The order of effectiveness of five chemical insecticides in respect of number of larva per infested plants over untreated control was $T_5 > T_4 > T_3 > T_1 > T_2$.

4.4.2 Yield of Sugarcane

4.4.2.1 Effect on healthy and infested cane weight (t ha^{-1})

Effect of different treatments on yield was evaluated in terms of healthy cane, infested cane and total cane yield (t ha^{-1}). The yield of healthy, infested and total canes per plot treated with different chemicals with different doses was shown in Table 4.4.28. The lowest yield (53.38 t ha^{-1}) of healthy cane in untreated control plot, having significant difference from other treatments. Infested cane yield (3.192 t ha^{-1}) was significantly lower in T_5 treatment plot as against the higher yield of (9.300 t ha^{-1}) being in untreated control plot. T_4 and T_3 treatments performed better in respect to infested cane yield than T_1 and T_2 treatment. There was no significant difference among infested cane yield of the T_4, T_3 and T_1, T_2 treated plots, respectively. A further analysis of the yield to assess the impact of each treatment on yield over control as shown in the same Table 4 suggested that T_5 treatment plot ensured higher increase (36.91%) of healthy cane yield. Treatment T_2 had the lower (14.83%) impact on increasing the healthy cane yield over control. Treatments T_5 and T_4 increased more than 30% of the healthy cane yield over control.

Table 4.4.28. Effect of different treatments on yield of sugarcane as affected by sugarcane stem borer infestation

Treatments	Yield of healthy cane (t/ha)	Percent increased yield of healthy cane over control	Yield of infested cane (t/ha)	Percent decreased yield of infested cane over control
T_1	64.70 d	17.48 d	5.278 bc	43.05 d
T_2	62.68 e	14.83 e	5.830 b	37.04 e
T_3	72.68 c	26.55 c	4.580 cd	50.58 c
T_4	77.89 b	31.45 b	3.817 de	58.60 b
T_5	84.62 a	36.91 a	3.192 e	65.54 a
T_6	53.38 f	-	9.300 a	-
$S_{\bar{x}}$	**0.4767**	**0.4514**	**0.18**	**1.103**
C.V.%	**1.38**	**3.55**	**6.88**	**4.33**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

4.4.2.2 Effect on total cane weight (t ha^{-1})

The total cane yield (87.81 t/ha) was the highest in T_5 (Nokotap 6G @ 50 kg ha^{-1}) treatment as against the lowest yield (62.68 t ha^{-1}) in untreated control shown in Figure 4.4.50 and Appendix 4.4.19. The highest yield decrease (65.54%) of infested cane was observed in T_5 treatment and as a cumulative impact on the highest increase (28.61%) of total cane yield was observed in the same treatment (Figure 4.4.51).

Previously, many studies also reported that use of different chemicals at different doses and time significantly reduced stem borer infestation and also increase sugarcane yield. Abdullah *et al.* (2005) showed the similar results when used Cartap 4G insecticides namely Seda 50SP, Padan 50SP, Cidan 4G, Razex 4G, Forwatap 4G, Sudan 4G and Padan 4G to evaluate their effectiveness against stem borer of sugarcane during 2001-2002 cropping season. An increase of 28.86 to 50.61% in yield was recorded in insecticide treated plots as compared to untreated ones.

Abdullah *et al.* (2005) also showed the similar results when used three cartap insecticides viz., Tenup 50SP, Forwatap 50SP and phartap 50SP at different doses and frequencies for the control of sugarcane stem borer, *Chilo tumidicostalis* Hampson at 3 locations in the cropping season 2003-2004. All the treated plots showed increased cane yield over control. Talpur *et al.* (2002) reported that Furadan 3G (carbofuran) applied at 12 kg ac^{-1}, padan 4G (cartap) at 9 kg ac^{-1}, Basudin 10G (diazinon) at 9 kg ac^{-1} and Thimet 5G (phorate) at 10 kg ac^{-1} increased cane yield over check plot.

Khan and Jan (1994) reported that Sevidol 4G, Curater 3G and Basudin 10G @ 25 kg ha^{-1} applied as side dressing followed by earthing-up reduced the stem borer infestation to 2.81, 7.34 and 17.89% but also increased the average cane yield up to 56.88, 56.62 and 44.31 tons ha^{-1} along with higher sugar yield of 7.86, 7.39 and 5.95 tons ha^{-1}. An increase of 28.86 to 50.61% cane yield was recorded in insecticide (Cidan 4G, Razex 4G, Forwatap 4G and Sundan 4G @ 3.0 kg a.i. ha^{-1}) treated plots as compared to untreated ones (Abdullah *et al.* 2005). Cidan 4G increased cane yield (22.32%) over control against stem borer infestation (Abdullah *et al.* 2005). Rana *et al.* (1992) reported that Furadan 3G and Curater 3G @ 4.86 kg ha^{-1} increased cane yield up to 11.67 -11.83 tons ha^{-1} against stem borer infestation.

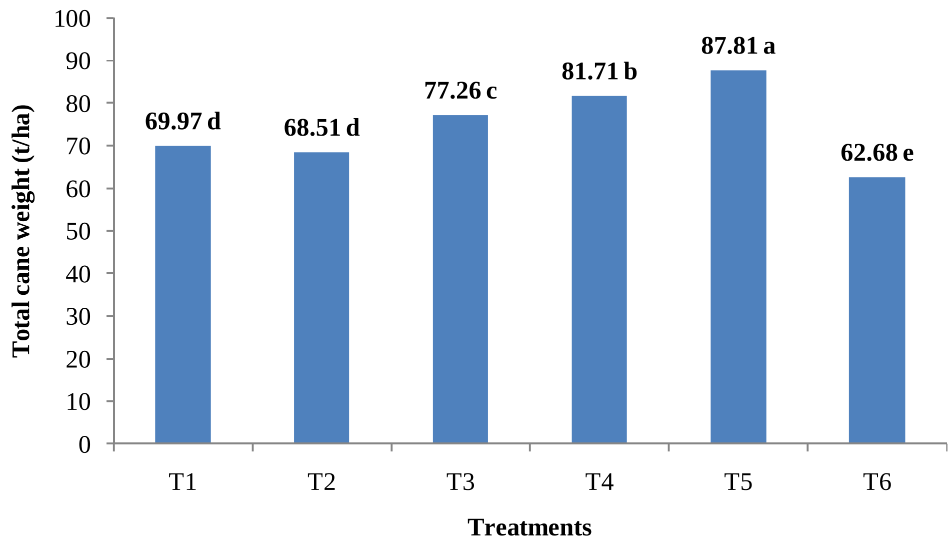

Figure 4.4.50. Yield of sugarcane under different treatments against sugarcane stem borer during January 2014 to December 2014. Bars having same letters are not significantly different (P<0.05, Duncan Multiple Range Test).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

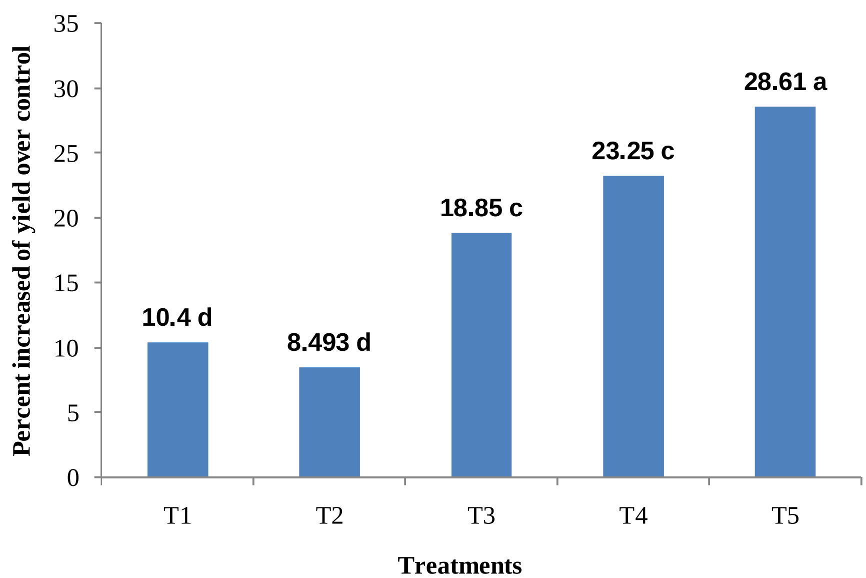

Figure 4.4.51. Percent increase yield of total cane over control under different treatments against sugarcane stem borer during January 2014 to December 2014. Bars having same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

4.5 Evaluation of some IPM Packages against sugarcane stem borer in field

5.5.1 Effect of IPM Packages on production of healthy stem and *C. tumidicostalis* infested stem

Number of healthy, infested and total canes and percent cane infestation caused by *C. tumidicostatlis* were significantly varied in different Integrated Pest Management packages. Table 4.5.29 indicated that the highest number of healthy canes per plot (573.70) was recorded from IPM package 7 treated plot, having significant variations with others packages. On the other hand, the lowest number of healthy canes per plot (375.70) was recorded in IPM package 9 treated plot which was significantly lower than other treated packages. In contrast, the highest number of infested canes (54.33/plot) was recorded from IPM package 9 treated plot, which was significantly higher than all other treated packages. The lowest number of infested canes (9.00/plot) was recorded in IPM package 7 treated plot, having significantly lower than any other packages.

Table 4.5.29 also expressed that the highest number of total canes (583.3/plot) was harvested from IPM package 7 treated plot, having significant variation from other package plots. The lowest number of canes (428.0/plot) was obtained from IPM package 9 treated plot, having significant difference from all other packages. Moreover, the lowest percentage of cane infestation (1.54%) by *C. tumidicostalis* was found in the plots treated with package 7 which was significantly different from all other package plots. On the other hand, the highest percent of plant infestation (12.31%) was recorded in package 9 (check variety) which was significantly different from all others packages.

Table 4.5.29 Number of healthy, infested and total canes per plot and percent cane infestation by stem borer under different IPM packages

IPM Packages	Number of canes/plot			Percent cane infestation by *C. tumidicostalis*
	Healthy	Infested	Total	
IPM Package 1	482.3 d	29.00 e	511.0 d	5.51 e
IPM Package 2	442.7 ef	39.00 c	481.7 ef	7.87 c
IPM Package 3	458.0 e	36.00 d	494.3 e	7.10 d
IPM Package 4	514.3 c	23.00 f	537.7 c	4.22 f
IPM Package 5	545.0 b	14.67 h	559.7 b	2.56 h
IPM Package 6	518.3 c	19.00 g	537.3 c	3.48 g
IPM Package 7	573.7 a	9.00 i	583.3 a	1.54 i
IPM Package 8	425.7 f	45.33 b	471.0 f	9.33 b
IPM Package 9 (check)	373.7 g	54.33 a	428.0 g	12.31 a
$S_{\bar{x}}$	**4.46**	**0.59**	**4.03**	**0.17**
CV (%)	**1.60**	**3.40**	**1.36**	**4.94**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg ha$^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

The effect of different IPM packages on percent reduction of infestation over control (check variety) has been presented in Figure 4.5.52 (Appendix 4.5.20). IPM package 7 reduced highest percentage (87.47%) of borer infestation over untreated control (check variety) followed by IPM package 5 (79.15%), IPM package 6 (71.74%) and IPM package 4 (65.67%) having significant difference among them. IPM Package 8 (resistant variety) reduced only 24% borer infestation over control (IPM package 9).

Result regarding healthy, infested and total number of cane per plot and percent cane infestation and pecent reduction of infestation due to *C. tumidicostalis* over untreated control (check variety) indicated that IPM package 7 comprising sugarcane variety Isd 36 + planting on 15 November + hand cutting and removal of infested stem + de-trashing of dead leaves + Nokotap 6G @ 50 kg ha^{-1} provided the best result with minimum percent of cane infestation and gave the highest percent reduction of borer infestation over control. The order of effectiveness of eight IPM packages against stem borer infestation over check variety was $P_7 > P_5 > P_6 > P_4 > P_1 > P_3 > P_2 > P_8$. These results partially agreed with the finding of Rahman *et al*. (2015) who obtained the highest efficiency of IMP package comprising planting of borer free sett + removal of primary stem borer infested cane + detrashing in June through September + Cidan 4G @ 3.0 kg ai ha^{-1} applied in June, July and August) against stem borer.

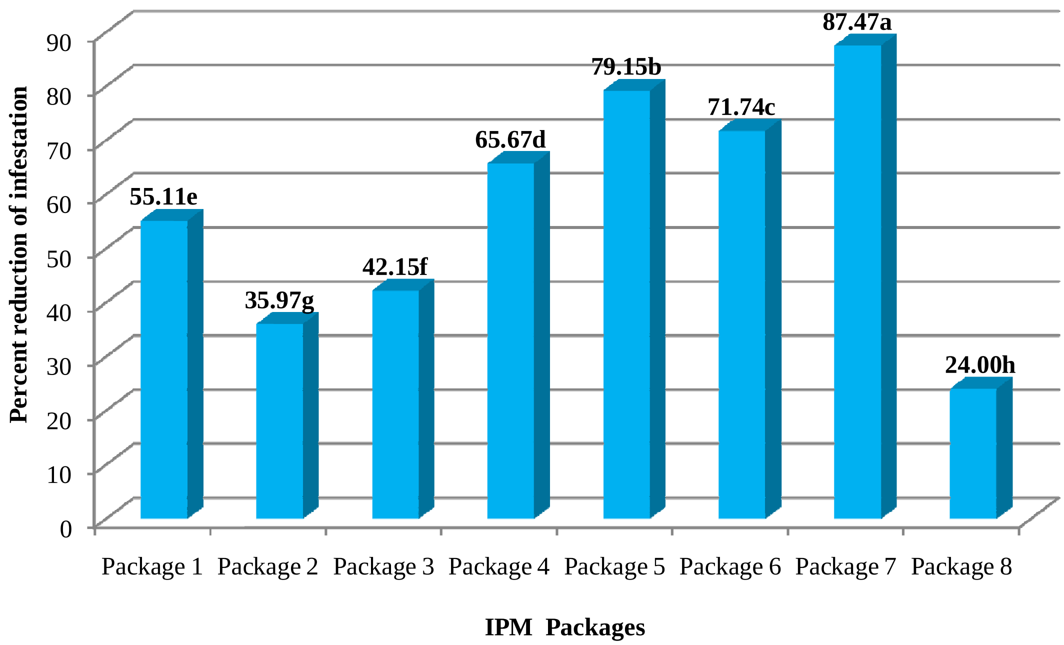

Figure 4.5.52 Percent reduction of stem borer infestation in eight IPM packages over control (check variety).

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg $ha^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

4.5.2 Effect of IPM packages on internode infestation per infested cane by *C. tumidicostalis*

The effect of different IPM packages on sugarcane stem borer was evaluated during stem formation. Significant variation was observed in number of healthy, infested and total internodes per cane in different IPM packages. The number of healthy, infested and total internodes per cane treated with different IPM packages is shown in Table 4.5.30. The highest number of healthy internodes per cane (22.91) was recorded from Package 7 treated plot followed by package 5 treated plot, having significant statistical variations with others packages. On the other hand, the lowest number of healthy internodes per cane (14.10) was recorded in package 9 treated plot, which was significantly lower than other package treated plots. In contrast, the highest number of infested internodes per cane (5.48) was recorded from package 9 treated plot, which was significantly higher than all other treated plots. The lowest number of infested internodes per cane (2.16) was recorded in package 7 treated plot followed by package 5 and package 6 treated plot, having significantly lower than other packages.

Table 4.5.30 also expressed that the highest number of total internodes per cane (25.07) was observed in IPM package 7 treated plot followed by IPM package 4, IPM package 5 and IPM package 6 treated plot having significant variation from other packages. The lowest number of internodes per infested cane (19.57) was obtained from IPM package 9 treated plot, having significant difference with other packages. The second lowest number of internodes per cane (21.24) was obtained from IPM package 8 treated plot followed by IPM package 1, IPM package 2 and IPM package 3 treated plots, having significant difference with other IPM packages.

The effect of different IPM packages on percent reduction of internodes infestation over control has been shown in Figure 4.5.53 (Appendix 4.5.21). IPM package 7 reduced highest percent (56.76%) of internode infestation by stem borer over untreated control (check variety) followed by IPM package 5 (48.03%), IPM package 6 (42.17%) and IPM package 4 (36.84%) having significant difference among them. IPM Package 8 (resistant variety) reduced only 10.84% internod infestation by stem borer over check variety.

The above results on the effectiveness of the packages on production of healthy internodes per plant and percent reduction of internodes infestation due to stem borer over control indicated that all the IPM packages reduced internode infestation by stem borer. IPM package 7 was the most effective package against stem borer attacks which gave maximum number of healthy internodes per plant (22.91) and reduced the highest percent of internode infestation (56.76%) compared to other packages. IPM package 5 and IPM package 6 reduced 48.03% and 42.17% internode infestation, respectively over check variety. The order of effectiveness of the eight tested IPM packages for the protection of internode infestation by sugarcane stem borer over check variety (T_9) was $P_7 > P_5 > P_6 > P_4 > P_1 > P_3 > P_2 > P_8$.

Table 4.5.30. Number of healthy, infested and total internodes per infested plant and percent internode infestation by stem borer under different IPM packages

Treatments	Number of internodes per infested plant			Percent internodes infestation per infested plant
	Healthy	Infested	Total	
IPM Package 1	19.09 cd	3.59 c	22.68 bcd	15.83 d
IPM Package 2	18.02 de	4.04 bc	22.06 cd	18.10 c
IPM Package 3	18.49 de	3.83 bc	22.31 bcd	17.12 c
IPM Package 4	20.40 bc	2.96 d	23.36 abc	13.67 e
IPM Package 5	21.44 ab	2.60 de	24.04 ab	11.25 g
IPM Package 6	20.91 b	2.74 de	23.64 abc	12.51 f
IPM Package 7	22.91 a	2.16 e	25.07 a	9.35 h
IPM Package 8	16.95 e	4.29 b	21.24 d	19.29 b
IPM Package 9 (check)	14.10 f	5.48 a	19.57 e	21.63 a
$S_{\bar{x}}$	**0.40**	**0.14**	**0.39**	**0.25**
CV (%)	**3.65**	**6.82**	**2.97**	**2.73**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg ha$^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

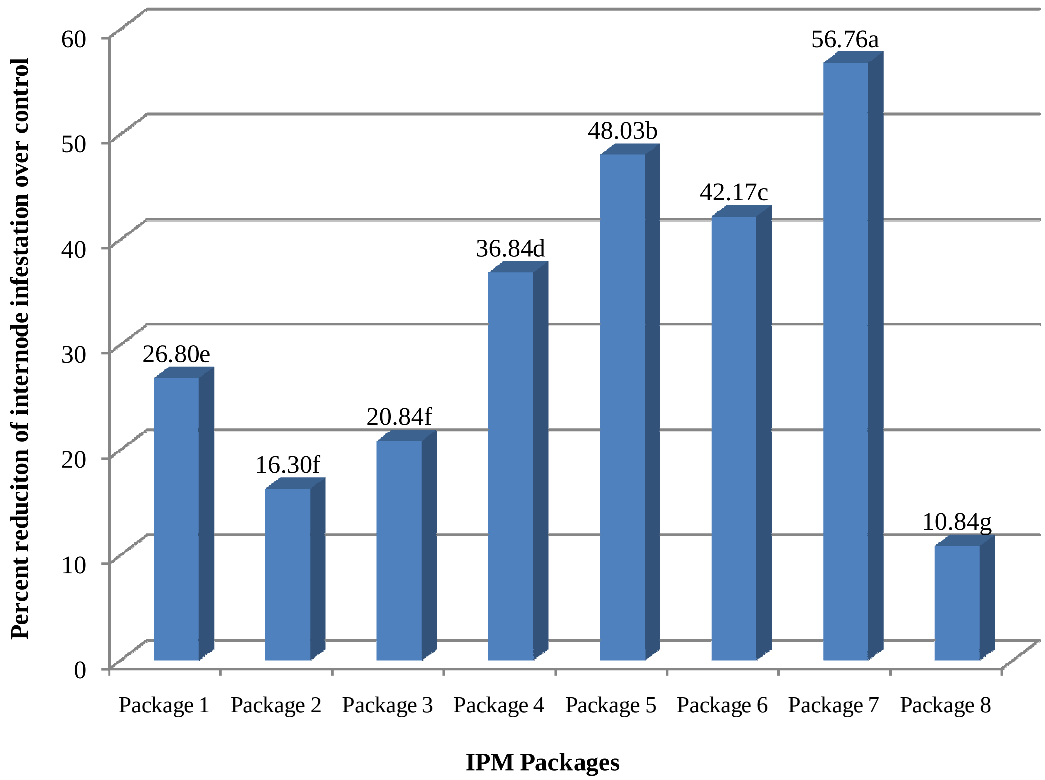

Figure 4.5.53 Percent reduction of internodes infestation by stem borer by 8 IPM packages over control (check variety).

4.5.3 Effect of IPM packages on populatin of stem borer larva per infested plant

The effect of different IPM packages on the population of stem borer larva in sugarcane is presented in Table 4.5.31. The lowest number of stem borer larva per infested plant (21.93 larvae/plant) was found in IPM package 7 having no significant difference with IPM package 5 (25.13 larvae/plant) and IPM package 6 (30.07 larvae/plant) but significantly different from others. In contrast, the highest number of larva per plant (67.67) was observed in IPM package 9 (checked plot) followd by IPM package 8 (62.93) having no significant variations between them. Similarly IPM package 7 reduced 67.35% lavae per infested plant over check variety followed by IPM package 5 which reduced 62.77% borer larvae per infested cane having no significant variation between them. Thus IPM package 7 was the most effective IPM packages in reducing the stem borer larvae per infested internodes of sugarcane. The order of effectiveness of the eight IPM packages for the protection of stem borer larval attack over check variety was $P_7 > P_5 > P_6 > P_4 > P_1 > P_3 > P_2 > P_8$.

Table 4.5.31 Effect of different IPM packages on population of stem borer larvae per infested sugarcane stem

Treatments	Number of larvae per infested plant	Percent reduction larvae per infested plant
IPM Package 1	37.93 cd	44.12 cd
IPM Package 2	47.73 b	28.83 e
IPM Package 3	41.87 bc	37.97 de
IPM Package 4	33.33 cde	50.37 c
IPM Package 5	25.13 ef	62.77 ab
IPM Package 6	30.07 def	55.57 bc
IPM Package 7	21.93 f	67.35 a
IPM Package 8	62.93 a	6.95 f
IPM Package 9 (check)	67.67 a	--
$S_{\bar{x}}$	**2.10**	**2.68**
C.V.%	**8.90**	**10.47**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg $ha^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

4.5.4 Effect of IPM packages on yield of sugarcane

Cane yield of sugarcane significantly varied in different IMP packages. The highest cane yield (81.65 t ha^{-1}) was observed in IPM package 7 treated plots followed 74.03 t/ha, 68.00 t/ha in IPM package 5 and package 6, respectively having significant variation among them (Table 4.5.32). On the other hand, the lowest cane yield (32.86 t/ha) was obtained in IPM package 9 (check variety) which was significantly lower than all other IMP packages. Similar trend was obtained in all IPM packages in respect of percent increase of sugarcane yield over check variety. IPM package 7 gave the best result by increasing 59.76% cane yield of sugarcane over check variety which was significantly higher than other IPM packages. IPM package 5 and 6 incrased 55.58% and 51.68% yield, respectively over check variety. IPM package 8 consiting sugarcane variety Isd Isd36 with planting on 15 November increased 23.95% yield over check variety which was the lowest (Table 4.5.32).

The result indicated that IPM package 7 comprising sugarcane variety Isd 36 + Planting on 15 November + Hand cutting and removal of infested stem + De-trashing of dead leaves + application of Nokotap 6G @ 50 kg ha^{-1} produced higher sugarcane yield compared to packages. The order of effectiveness of IPM packages for the production of sugarcane and percent increase of yield against stem borer infestation over check variety was $P_7 > P_5 > P_6 > P_4 > P_1 > P_3 > P_2 > P_8$. These results partially agreed with the report of Rahman *et al.* (2015) who ovserved higher cane yield (72.33 ton ha^{-1}) in IPM package (comprising planting of borer free sett + removal of primary stem borer infested cane + detrashing in June through September + application of Cidan 4G @ 3.0 kg ai ha^{-1} in June, July and August) against stem borer. Morereover, Khan and Khan (2006) reported that combined application of IPM methods viz., mechanical + cultural + biological and mechanical + cultural +

chemical control resulted in lowering borer infestation and provided the highest cane yield (104.31 t ha^{-1}) with highest sugar yield (13.62 t ha^{-1}) especially in plant crop.

Table 4.5.32 Effect of different IPM packages on the population of stem borer per infested sugarcane stem

Treatments	Cane yield (t/ha)	Percent increase of cane yield over control
IPM Package 1	57.83 e	43.15 d
IPM Package 2	49.67 g	33.83 f
IPM Package 3	52.59 f	37.50 e
IPM Package 4	64.84 d	49.32 c
IPM Package 5	74.03 b	55.58 b
IPM Package 6	68.00 c	51.68 c
IPM Package 7	81.65 a	59.76 a
IPM Package 8	43.25 h	23.95 g
IPM Package 9 (check)	32.86 i	-
$S_{\bar{x}}$	**0.6899**	**0.769**
C.V.%	**2.05**	**3.00**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg $ha^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

4.5.5 Benefit Cost Ration (BCR)

Benefit cost analysis of eight packages for the management of stem borer attacking sugarcane is presented in Table 4.5.33. The highest net return of Tk. 195787.50 was obtained from IPM package 7 (Isd 36 + planting on 15 November + hand cutting and removal from field + de-trashing + application of Nokotap 6G @ 50 kg ha^{-1}) followed by Tk. 186082.5 and Tk.164250.0 in IPM package 5 and package 6, respectively. On the other hand, the lowest net return (TK. 90365.00) was obtained from check variety and IPM package 8 (variety Isd 36 planting on 15 November) gave Tk. 118937.50 net retrun which was also higher than the check variety. In case of Benefit Cost Ratio (BCR), IPM package 1 (Isd 36 + planting on 15 November + hand cutting and removal from field) provided the highest result (10.44) followed by 5.47 and 4.10 in IMP package 5 (Isd36 + planting on 15 November + hand cutting and removal from field + application of Nokotap 6G @ 50 kg ha^{-1}) and 4 (Isd 36 + planting on 15 November + hand cutting and removal from field + de-trashing). IPM package 1 was the best considering BCR and environmental safety point of view but total production and net return was lower than other IPM packages. IPM package 7 might be accepted considering the total production of sugarcane and net return.

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Table 4.5.33 Economic analysis of eight Integrated Pest Management (IPM) packages over check variety for the management of sugarcane stem borer

Treatments	No. of insecticide application	No. of infested cane cutting	No. of detrashing	Cost of insecticide (Tk.)	Labour					Total cost (TK)	Yield of healthy cane (t/ha)	Gross return (TK/ha)	Net return	Adjusted net return (TK/ha)	Benefit cost ratio (BCR)
					Cutting of infested cane	Detrashing	Insecticide	Labour	Cost (Tk.)						
T_1= IPM Package 1	0	6	0	0.0	24	0	0	24	6000	6000.0	57.83	159032.5	153032.5	62667.5	10.44
T_2= IPM Package 2	0	0	3	0.0	0	45	0	45	11250	11250.0	49.67	136592.5	125342.5	34977.5	3.11
T_3= IPM Package 3	3	0	0	5500.0	0	0	24	24	6000	11500.0	52.59	144622.5	133122.5	42757.5	3.72
T_4= IPM Package 4	0	6	3	0.0	24	45	0	69	17250	17250.0	64.84	178310.0	161060.0	70695.0	4.10
T_5= IPM Package 5	3	6	0	5500.0	24	0	24	48	12000	17500.0	74.03	203582.5	186082.5	95717.5	5.47
T_6= IPM Package 6	3	0	3	5500.0	0	45	24	69	17250	22750.0	68.00	187000.0	164250.0	73885.0	3.25
T_7= IPM Package 7	3	6	3	5500.0	24	45	24	93	23250	28750.0	81.65	224537.5	195787.5	105422.5	3.67
T_8= IPM Package 8	0	0	0	0.0	0	0	0	0	0	0.0	43.25	118937.5	118937.5	0.0	0
T_9= IPM Package 9	0	0	0	0.0	0	0	0	0	0	0.0	32.86	90365.0	90365.0	0.0	0

BCR= Benefit Cost Ration

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting and removal of infested cane + De-trashing + Nokotap 6G @ 50 kg $ha^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 40) + Planting on 15 November.

Chapter V

SUMMARY AND CONCLUSION

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Sugarcane stem borer (*Chilo tumidicostalis* Hampson) is one of the most injurious insect pests of sugarcane in the world and considered as a vital problem for economic production of this crop. Five experiments were conducted in the field and laboratory to achieve the objectives of the study: seasonal abudance, varital resistance and integrated management of sugarcane stem borer, *C. tumidicostalis* Hampson. Farmers opinion on pest satus and infestation intensity of stem borer were collected from 15 upazilas under 9 major sugarcane growing districts which covered 8 (eight) sugar mills under 6 agro-ecological zones of Bangladesh. Infestation data of *C. tumidicostalis* was collected directly from 90 plots of sugarcane growers and 10 plots of BSRI. Infestation intensity of stem borer was also recorded from experimental plots at BSRI in 2014, 2015 and 2016. Sugarcane was planted on six dates starting from September 2014 at 30 days interval to observe the effect of planting dates on *C. tumidicostalis* at BSRI experimental field. Infestation intensity of stem borer was recored from different planting dates.

Ten sugarcane varieties were cultivated in farmer's field at Natore Sugar Mills Zone area to study the effect of varieties on stem borer infestation and to find out the resistant variety. Different biophysical and biochemical characteristics of ten sugarcane varieties were studied in the laboratories of SAU, BSRI, SRDI and BCSIR. Five chemical insecticides of different groups and formulation were tested against the *C. tumidicostalis* in sugarcane field at BSRI firm to find out the effective chemical insecticides against stem borer. Finaly some Integrated Pest Management (IPM) packages consisting resistant varieties, suitable planting dates, detrashing, hand cutting and destruction of larvae, effect of chemical insecticides were evaluated against the stem borer to develop suitable IPM packages. This experiment was also done at the farmer's field at Joypurhat Sugar Mills

Zone during November 2015 to December 2016. Results of different experiments have summarized herein.

Sugarcane grower's reported several problems of sugarcane such as: long duration crop, low price of cane, insect pests attack, disease infestation, low yield, delayed payment of cane price and high labour cost. Of these insect pest attack was an important problem for sugarcane cultivation and stem borer was the important one in major sugarcane growing regions of Bangladesh. Stem borer infestation varied from 12.44-17.20% in farmer's field. The lowest percent of stem infestation (12.44%) was recorded from Natore Sador as against the highest (17.20%) from Ishurdi. Sugarcane growers reportred three methods such as cultural (detrashing), mechanical (hand cutting and destruction of larva) and chemical insecticides for the management of sugarcane stem borer but majority of them (48.08%) applied chemical insecticides. They reported the application of carbofuran, virtaco and lorsban insecticides for the stem borer management but most of farmers used carbofuran.

In experimental plot at BSRI, stem infestation by *C. tumidicostalis* varied from 20.88% to 24.71% during 2014, 2015, 2016 as cumulative infestation. *C. tumidicostalis* started infestation from May and increased gradually with the age of the crops up to September then declined and sharply decreased after October and no new infestation occurred in November. The peak infestation of *C. tumidicostalis* was observed in September every year in both treatements (infested plant cut and removed from the field and infested stems left untouched in the field). Environmental temperature and rainfall had significant effect on sugarcane stem infestation by *C. tumidicostalis*. Postive relationship was observed between *C. tumidicostalis* infestation and temperature or rainfall in 2014, 2015 and 2016.

Sugarcane stem infestation by *C. tumidicostalis* varied from 8.08-17.86% in six planting dates. The lowest percent stem infestation (8.08%) was observed in T_3 treatment (planting date on 15th November) having significant difference with others as against the highest in T_1 (planting date on 15th September). Higher level of infestation was found in early planting crops compared to late plantiation. Percent internode infestation (18.66%) was also the lowest in T_3 treatment (planting date on 15th November). This treatement also gave higher amount of healthy (84.41 t ha^{-1}) and total yield (88.99 t ha^{-1}) compared to other planting dates.

Percent cane infestation was also varied from 5.79-27.39% in ten sugarcane varieties and the lowest percent infestation (5.79%) was recorded in Isd 36 variety as against the highest in Isd 40 (27.39). Percent internode infestation by *C. tumidicostalis* was found lowest (9.83%) in the sasme varieity (Isd 36). This variety also gave the highest amont of healthy cane yield (79.34 t ha^{-1}) compared to others. In case of biophysical characteristics, length of leaf sheath and leaf blade, and percent fiber content of the stem contributed resistant mechanism against *C. tumidicostalis*. Negative relationship was observed between *C. tumidicostalis* and biophysical characteristics of ten sugarcane varieties. In case of biochemical characteristics brix percentage, pole percent cane, percent reducing sugar, nitrogen, phosphorous, potassium and silicon content of the varieties exert resistant power. These compounds and elements have negative impact on stem borer infestation. Sugarcane variety with higher amount of these chemicals had lower level of stem borer infestation. Strong negative relationship was existed between stem borer infestation and presence of phosphorous, potassium and silicon content of sugarcane vrieties.

In case of chemical control, *C. tumidicostalis* infestation was found lowest (4.51%) in T_5 (Nokotap 6G @ 50 kg ha^{-1}) treated plots which gave 79.53% reduction of cane infestation over untreated control followed by T_4 (Cidan 4G @ 75 kg ha^{-1}) that reduced 72.54% infestation over control. Treatemnt 2 (Carbofuran 5G @ 40 kg ha^{-1}) provided minimum protection against *C. tumidicostalis* compared to others. The higher amont of healthy (84.62 t/ha) and total cane yield (87.81 t/ha) was also recorded from the T_5 (Nokotap 6G @ 50 kg ha^{-1}) treated plots which also increased highest percent of cane yield (28.61%) over untreated control.

Integrated Pest Management (IPM) packages significantly reduced *C. tumidicostalis* infestation on sugarcane and increased cane yield. The best result was obtained from the IPM package 7 (Isd 36 variety + planting on 15 November + hand cutting and removal of infested cane + de-trashing + application of Nokotap 6G @ 50 kg ha^{-1}) which had only 1.54% stem infestation as against the highest (12.31%) in IPM packge 9 (Isd 40 variety + planting on 15 November). This package (IPM package 7) provided maximum reduction (87.45) of infestation over IPM package 9. Percent internode infestation and number of larvae/infested plant was also found to be the lowest in this package. The highest amount of cane yield (74.03t ha^{-1}) also recorded from the same package (IPM package 7). In case of benefit csot analysis, IPM package 7 (Isd 36 variety + planting on 15 November + hand cutting + de-trashing + application of Nokotap 6G @ 50 kg ha^{-1}) gave the highest net return of Tk. 195787.50 and was obtained from followed by Tk. 186082.5 and Tk.164250.0 in IPM package 5 and package 6, respectively. On the other hand, the lowest net return (TK. 90365.00) was obtained from check variety (IPM package 9). Considering Benefit Cost Ratio (BCR), IPM package 1 (Isd 36 variety + planting on 15 November + hand cutting) gave the highest result (10.44) followed by 5.47 and 4.10 in IMP package 5 (Isd 36 variety + planting on 15 November + hand cutting + application of Nokotap 6G @ 50 kg ha^{-1}) and 4 (Isd 36 + planting on 15 November + hand cutting + De-trashing).

CONCLUSION

Based on the overall results of the study the following conclusions are drawn:

- Insect pest is one of the major constraints for sugarcane production and stem borer (16.42%) is one of major problem for sugarcane production and *C. tumidicostalis* was the major pest. Farmers used cultural (burning of leaves after harvest, de-trashing etc), mechanical (cutting of infested cane and destruction of larva) and chemical methods for combating this pest but chemical control was widely used method.
- Sugarcane stem infestation by *C. tumidicostalis* varied from 12.44% -17.20% in farmer's field at different regions under survey during 2014 but in the experimental field, infestation varied from 20.88% to 24.71% during 2014, 2015 and 2016 as a cumulative infestation.
- Stem borer infestation initially started from May and gradually increased with the age of the crop up to September then declined. High infestation occurred in September and no infestation occurred in November.
- Environmental temperature and rainfall had profound effect on *C. tumidicostalis* infestation. Strong positive relationships were existed between percent cane infestation by stem borer and temperature or rainfall.
- Early planting crops had higher level of infestation compared to late planting crops. Considering minimum cane infestation and higher cane yield, 15th November was the most suitable planting date for sugarcane.
- Among the 10 sugarcane varieties, Isd 36 showed better performance having lowest percentage of *C. tumidicostalis* infestation and highest yield compared to

other varieties. Morphological characteristics such as length of leaf sheath and leaf blade, fiber contents exerted resistant mechanism of the sugarcane varieties. Negative relationship was observed between *C. tumidicostalis* infestation and biophysical characteristics of the varieties.

- Biochemical compounds such as brix percent, pol percent cane, percent reducing sugar and nutrient elements like nitrogen, phosphorous, potassium, silicon content of the sugarcane varieties induced resistant quality agianst *C. tumidicostalis*. Strong negative relationship was observed between stem borer infestation and presence of higher amount of phosphorous, potassium and silicon content of sugarcane vrieties.
- Chemical insecticides significantly redueced sugarcane stem borer infestation but Nokotap 6G @ 50 kg ha^{-1} showed superior performance by reducing highest percentage of *C. tumidicostalis* infestation and producing maxium cane yield over untreatred control.
- Among the nine tested IPM packages for the management of sugarcane stem borer, IPM package 7 (Isd 36 variety + planting on 15 November + hand cutting and removal of infested cane + de-trashing + Nokotap 6G @ 50 kg ha^{-1}) gave the better result by providing highest reduction of *C. tumidicostalis* infestation and provided maximum cane yield over untreatred control. The higher net return of Tk. 195787.50 was also obtained from this IPM package comparted to others but maximum Benefit Cost Ratio (BCR) was gained from IPM package 1 (Isd 36 variety + planting on 15 November + hand cutting) and gave the highest result (10.44).

RECOMMENDATIONS

- Sugarcane planting date in Bangladesh is September to February. Mid planting date like 15th November is the better than other planting date. Avoid early and late plantation.
- Sugarcane varieties like Isd 36, Isd 26, and Isd 37 may be recommended for commercial cultivation to protect against *C. tumidicostalis* in Bangladesh.
- Nitrogen, phosphorous and potassium fertilizers may be used in balanced way for the management of *C. tumidicostalis*. Further study may be conducted for balanced use of fertilized against stem borer.
- Experiment with Silicon content may be conducted for the management of *C. tumidicostalis* on sugarcane.
- IPM package consisting cultivation of variety Isd 36 + planting on 15 November + hand cutting and removal of infested cane + de-trashing + application of Nokotap 6G @ 50 kg ha^{-1} may be used for the management of sugarcane stem borer.

Chapter VI

LITERATURE CITED

CHAPTER VI

LITERATURE CITED

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LIST OF APPENDICES

Appendix 3.1.1. Questionnaire for Collecting Information from the Farmers

Sl no: Date:

Information collection for infestation intensity, damage severity and management practices of stem borer from farmer's interview

1. Farmer's name: ....
2. Address: Village: ....
3. Union:.......................... Upazilla: .... District:.............. Mobile No:...............
4. Male/Female:..................5. Age:..................Year

6. Educational Background: No Education / Primary / SSC / HSC / Graguate
7. Total cultivated land: ....Decimal /Acare
8. Sugarcane cultivated land:.................... Decimal /Acare
9. Experience of sugarcane cultivation:......... Year
9. Variety: Isd/BSRI Akh..
10. Have any training on sugarcane cultivation ? Yes/No ,
    If yes, Name of organization: Sugar Mill/ BSRI/DAE
11. Have any problems on sugarcane cultivation? Yes/No,
    If yes, Name the problems: ....
12. What types of insect pests infestation occured in cane, damage percentage and name of control measures

Sl. no.	Insect pests	Damage percentage (Small amount:0-10%, Middle amount: 11-20%, High amount: 20% above)	Control measures
1	ESB	Small / Middle / High	
2	TSB	Small / Middle / High	
3	SB	Small / Middle / High	
4	RSB	Small / Middle / High	
5	Termite		

13. Name of sugarcane disease, damage percentage and name of control measures

Sl. no.	Disease	Damage percentage (Small amount:0-10%, Middle amount: 11-20%, High amount: 20% above)	Control measures
1	Red rot	Small / Middle / High	
2	Wilt	Small / Middle / High	
3	Smut	Small / Middle / High	

14. Insect pests of sugarcane stem. Yes/No, If yes, damage percentage and control measures

Sl. no.	Insect pest	Damage percentage (Small amount:0-10%, Middle amount: 11-20%, High amount: 20% above)	Control measures
1	Stem Borer	Small / Middle / High	

15. Stem borer first attack in the field in which month?..............
Highest infestation occur in which month ?...............
Last infestation occur up to which month?..................

16. Which chemical insecticide use to control stem borer, doses and times of application?

SL	Chemical insecticide	Doses	Times of application
1			
2			
3			

17. Have any relationship to red rot with stem borer infestation? Yes / No.
If yes, Losses amount: Small / Middle / High.

1**8**. Have any training for control stem borer ? Yes / No, If yes, Name of organization: Sugar Mill/ BSRI/DAE

19. Source of sugarcane seed? Self produced seed/ Collect from others farmer/ Sugar Mill.

Farmer's signature and date

Appendix 3.1.2. Insect pest survey form

Sereal no: Date:

study on the pest status of sugarcane stem borer in major sugarcane growing regions in bangladesh

1. Farmers name: ....
2. Address:
   (a)Village: .... (b) Post: ....
   (c) Upozilla: .... (d) Zilla ....
   (e) Contract no.: ....
3. Surveyed land area: .... acre
4. Date of Plantation: .... 5. Variety:.... Isd. ....

5. Counted plants and S.B.Infested plants

	Counted plants	S.B. Infested plants	Mean	% infestation
Ist row				
2nd row				
3rd row				
Total				

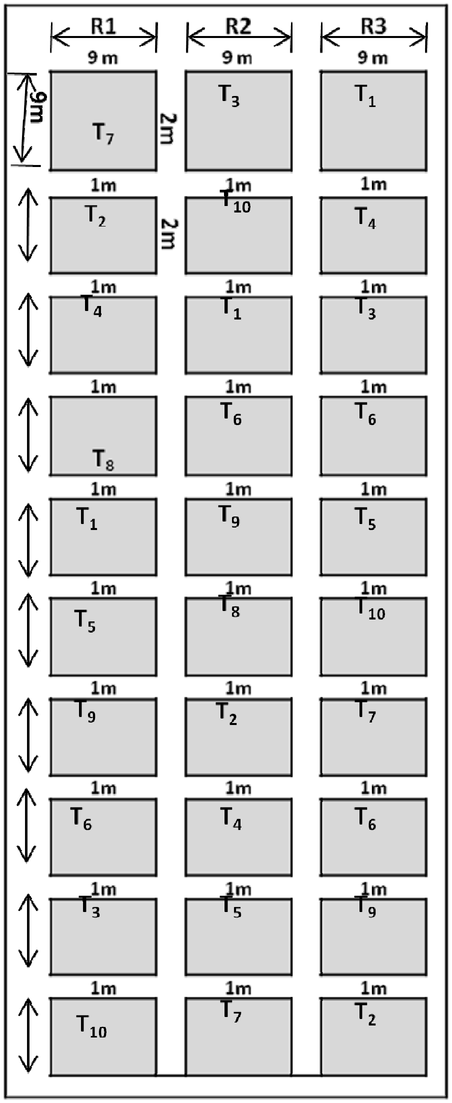
Appendix 3.2.3. Monthly mean weather data of the experimental site during September 2014 to December 2015 at BSRI, Ishordi, Pabna

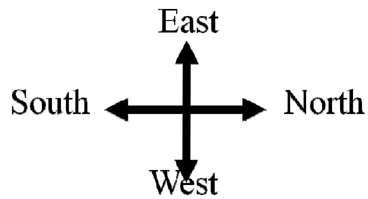
Year	**Month**	**Average RH (%)**	**Maxi.^{0}C**	**Mini.^{0}C**	**Average**	**Total Rain fall (mm)**
2014	September	92.01	30.59	27.35	28.97	4.24
2014	October	91.24	28.86	25.16	27.01	1.85
2014	November	86.07	26.54	18.90	22.72	0.00
2014	December	87.18	19.75	13.55	16.65	0.00
2015	January	87.62	19.93	13.02	16.47	0.00
2015	Februay	70.98	23.36	15.83	19.60	0.00
2015	March	84.77	27.70	19.65	23.67	1.13
2015	April	90.67	28.47	22.64	25.56	2.49
2015	May	89.70	30.99	26.18	28.59	3.54
2015	June	88.90	30.94	27.20	29.07	8.86
2015	July	89.92	30.00	26.71	28.35	12.93
2015	August	91.86	29.54	27.03	28.29	4.31
2015	September	90.55	29.11	26.63	27.87	4.83
2015	October	88.93	27.14	24.56	25.85	1.59
2015	November	81.10	21.58	19.13	20.35	0.00
2015	December	83.95	18.14	15.34	16.74	0.00

Appendix 3.3.4: Monthly mean weather data of the experimental site during November 2014 to December 2015 at BSRI, Ishordi, Pabna

Year	Month	Temperature (^{O}C)			Rainfall (mm)
		Maximum	Minimum	Average	
2014	November	26.54	18.90	22.72	0.00
2014	December	19.75	13.55	16.65	0.00
2015	January	19.93	13.02	16.47	0.00
2015	Februay	23.36	15.83	19.60	0.00
2015	March	27.70	19.65	23.67	1.13
2015	April	28.47	22.64	25.56	2.49
2015	May	30.99	26.18	28.59	3.54
2015	June	30.94	27.20	29.07	8.86
2015	July	30.00	26.71	28.35	12.93
2015	August	29.54	27.03	28.29	4.31
2015	September	29.11	26.63	27.87	4.83
2015	October	27.14	24.56	25.85	1.59
2015	November	21.58	19.13	20.35	0.00
2015	December	18.14	15.34	16.74	0.00

Appendix 3.3.5. Layout of the experimental field during November 2014 to December 2015





Plot size = 9m × 9m
Plant spacing = End to End of the setts
Block to block distance = 2m
Plot to plot distance = 1m

Appendix 4.1.6. Farmer's response on training of sugarcane cultivation

Name of organization	Respondents as training of one organization	Respondents as training of two organization	Respondents as training of three organization	Total Respondents	Respondents (%)
Sugar mill	97	0	0	97	74.62
BSRI	1	25	0	26	20.00
DAE	0	1	6	7	5.38
Total	**98**	**26**	**6**	**130**	**100**

Appendix 4.1.7. Source of sugarcane seeds for cultivation

Seed Source	Respondents as user of one seed source	Respondents as user of two seed source	Respondents as user of three seed source	Total Respondents	Respondents (%)
Self	84	0	0	84	68.29
Other farmers	15	18	0	33	26.83
Sugar Mill	1	5	0	6	4.88
Total	**100**	**23**	**0**	**123**	**100**

Appendix 4.1.8. Farmer's information on sugarcane yield losses by stem borer

% Damage/losses of sugarcane in field	No. of respondents
No loss	0
1-5%	12
5.01-10%	32
10.01-15%	50
15.01-20%	6
Total	**100**

Appendix 4.1.9. Farmer's response on stem borer control by chemical insecticides

Chemical control	Respondents as Ist chemical	Respondents as 2nd chemical	Respondents as 3rd chemical	Total	Respondents %
Carbofuran	79	0	0	79	75.24
Virtako	0	19	0	19	18.10
Lorsban	0	5	2	7	6.67
Total	**79**	**24**	**2**	**105**	**100.00**

Appendix 4.1.10. Trends of sugarcane stem infestation by *C. tumidicostalis* on sugarcane in infested stem cutting field in 2014, 2015 and 2016

New infestation data												
Year	January	February	March	April	May	June	July	August	September	October	November	December
Year 2014	0	0	0	0	2.78	4.66	6.80	8.96	12.72	11.12	0.00	0.00
Year 2015	0	0	0	0	3.32	5.42	7.98	10.28	13.98	12.38	0.00	0.00
Year 2016	0	0	0	0	2.02	3.79	5.88	7.48	11.32	9.72	0.00	0.00

Appendix 4.1.11. Trends of sugarcane internodes infestation by *C. tumidicostalis* on sugarcane in infested stem cutting field during 2014, 2015 and 2016

Year	January	February	March	April	May	June	July	August	September	October	November	December
2014	0	0	0	0	14.30	16.30	18.42	21.00	21.90	20.20	0.00	0.00
2015	0	0	0	0	16.00	17.62	19.70	22.20	23.08	21.88	0.00	0.00
2016	0	0	0	0	13.30	15.30	17.58	19.74	20.62	18.92	0.00	0.00

Appendix 4.1.12. Trends of number of larva in infested cane by *C. tumidicostalis* on sugarcane in infested stem cutting field during 2014, 2015, 2016

Year	January	February	March	April	May	June	July	August	September	October	November	December
2014	0	0	0	0	44.00	36.00	30.00	26.00	20.00	15.67	0	0
2015	0	0	0	0	48.00	45.00	36.00	32.00	27.00	19.00	0	0
2016	0	0	0	0	38.00	31.33	27.00	23.00	17.00	11.33	0	0

Appendix 4.1.13. Trends of sugarcane stem infestation by *C. tumidicostalis* in experimental plots where infested stem kept inthe field during 2014, 2015, 2016

Cumulative data												
Year	January	February	March	April	May	June	July	August	September	October	November	December
Year 2014	0	0	0	0	3.88	10.12	16.13	23.49	33.76	36.76	36.76	36.76
Year 2015	0	0	0	0	3.68	8.16	14.24	20.69	31.78	34.78	34.78	34.78
Year 2016	0	0	0	0	2.67	6.08	12.09	18.58	29.65	32.65	32.65	32.65

Appendix 4.1.14. Trends of sugarcane internodes infestation by *C. tumidicostalis*in experimental plots where infested stem kept in the field during 2014, 2015 and 2016

Year	January	February	March	April	May	June	July	August	September	October	November	December
2014	0	0	0	0	15.46	21.04	26.79	32.32	37.22	39.32	39.32	39.32
2015	0	0	0	0	17.83	23.30	29.42	35.30	39.80	41.50	41.50	41.50
2016	0	0	0	0	12.89	18.07	24.02	30.37	34.91	36.61	36.61	36.61

Appendix 4.1.15. Trends of number of larva of *C. tumidicostalis*in infested cane in the experimental plots where infested stem kept in the field during 2014, 2015, 2016

Year	January	February	March	April	May	June	July	August	September	October	November	December
2014	0	0	0	0	56.00	52.33	48.33	42.33	35.33	28.00	0.00	0.00
2015	0	0	0	0	71.33	65.67	60.67	54.67	48.00	42.00	0.00	0.00
2016	0	0	0	0	64.00	59.33	55.33	50.00	44.00	37.00	0.00	0.00

Appendix 4.2.16. Effect of planting dates on percent stem infestation of sugarcane by *C. tumidicostalis* during the period from September 2014 to December 2015

Treatments	**Percent stem borer infestation**
T_1	17.86 a
T_2	14.52 b
T_3	8.08 e
T_4	11.05 c
T_5	10.24 cd
T_6	9.82 de
$S_{\bar{x}}$	0.2885
C.V.%	**5.01**

Appendix 4.2.17. Sugarcane internodes infestation percentage by *C. tumidicostalis*in 2015at six planting dates

Treatments	**Percent Internodes infestation**
T_1	27.87 a
T_2	23.97 b
T_3	18.66 c
T_4	25.27 ab
T_5	23.05 b
T_6	22.45 b
$S_{\bar{x}}$	**0.8465**
C.V.%	**7.18**

Appendix 4.4.18. Effect of different treatments on percentage internodes/plant infestation by sugarcane stem borer during January 2014 to December 2014

Treatments	Percent internodes infestation	Percentage reduction of Internodes infestation over control
T_1	24.48 b	48.86 d
T_2	27.70 b	42.17 e
T_3	20.48 c	57.02 c
T_4	17.22 c	64.16 b
T_5	12.85 d	73.21 a
T_6	48.06 a	-
$S_{\bar{x}}$	**0.9018**	**1.458**
C.V.%	**7.18**	**5.11**

In a column, means followed by same letter(s) are not significantly different at *p= 0.05* by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

Appendix 4.4.19. Yield of sugarcane under different treatments against sugarcane stem borer during January 2014 to December 2014

Treatments	Weight of total cane(t/ha)	Percent increased yield of total cane over control
T_1	69.97 d	10.40 d
T_2	68.51 d	8.493 d
T_3	77.26 c	18.85 c
T_4	81.71 b	23.25 b
T_5	87.81 a	28.61 a
T_6	62.68 e	-
$S_{\bar{x}}$	**0.5529**	**0.4712**
C.V.%	**1.48**	**5.26**

In a column, means followed by same letter(s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

[T_1= Care 4G@ 75 kg ha^{-1}, T_2= Carbofuran 5G @ 40 kg ha^{-1}, T_3= Virtaco 40WG @ 300 g ha^{-1}, T_4= Cidan 4G @ 75 kg ha^{-1}, T_5 = Nokotap 6G @ 50 kg ha^{-1}, and T_6= untreated (control)].

Appendix 4.5.20. Percent reduction of stem borer infestation in eight IPM packages over control (check variety)

Treatments	Percentage of plant infestation	Percent reduction of infestation over control
Package 1	5.51 e	55.11 e
Package 2	7.87 c	35.97 g
Package 3	7.10 d	42.15 f
Package 4	4.22 f	65.67 d
Package 5	2.56 h	79.15 b
Package 6	3.48 g	71.74 c
Package 7	1.54 i	87.47 a
Package 8	9.33 b	24.00 h
Package 9	12.31 a	-
$S_{\bar{x}}$	**0.17**	1.437
C.V.%	**4.94**	4.32

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting+ De-trashing + Nokotap 6G @ 50 kg ha$^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 34) + Planting on 15 November.

Appendix 4.5.21. Percent reduction of internodes infestation by stem borer in 8 IPM packages over control (check variety)

Treatments	Percent internodes infestation	Percentage reduction of Internodes infestation over control
Package 1	15.83 d	26.80 e
Package 2	18.10 c	16.30 f
Package 3	17.12 c	20.84 f
Package 4	13.67 e	36.84 d
Package 5	11.25 g	48.03 b
Package 6	12.51 f	42.17 c
Package 7	9.35 h	56.76 a
Package 8	19.29 b	10.84 g
Package 9	21.63 a	-
$S_{\bar{x}}$	0.2429	1.261
C.V.%	2.73	6.75

IPM Package 1= Isd 36 + Planting on 15 November + Hand cutting, **IPM Package 2**= Isd 36 + Planting on 15 November + De-trashing, **IPM Package 3**= Isd 36 + Planting on 15 November + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 4**= Isd 36 + Planting on 15 November + Hand cutting + De-trashing, **IPM Package 5**= Isd 36 + Planting on 15 November + Hand cutting + Nokotap 6G @ 50 kg ha^{-1},**IPM Package 6**= Isd 36 + Planting on 15 November + De-trashing + Nokotap 6G @ 50 kg ha^{-1}, **IPM Package 7**=Isd 36 + Planting on 15 November + Hand cutting+ De-trashing + Nokotap 6G @ 50 kg $ha^{-1,}$ **IPM Package 8**= Isd 36 + Planting on 15 November and **IPM Package 9=** Check variety (Isd 34) + Planting on 15 November.

Appendix 4.5.22 Costs incurred per hectare in different IPM packages applied against stem borer on sugarcane

Package	Items of expenditure	Cost (Tk.)
Package 1	Total no. of labors for using infested cane cutting 6 x 4 x250[a]	6000.00
	Total cost	**6000.00**
Package 2	Total no. of labors for de-trashing 3 x 15 x 250[a]	11250.00
	Total cost	**11250.00**
Package 3	Total no. of labors for applying insecticides 3 x 8 x 250.00[a]	6000.00
	Nokotap 6G (for 3 times) 50 x 110.00 [b]	5500.00
	Total cost	**11500.00**
Package 4	Total no. of labors for using infested cane cutting 6 x 4 x250[a]	6000.00
	Total no. of labors for de-trashing 3 x 15 x 250[a]	11250.00
	Total cost	**17250.00**
Package 5	Total no. of labors for using infested cane cutting 6 x 4 x250[a]	6000.00
	Total no. of labors for applying insecticides 3 x 8 x 250.00[a]	6000.00
	Nokotap 6G (for 3 times) 50 x 110.00 [b]	5500.00
	Total cost	**17500.00**
Package 6	Total no. of labors for de-trashing 3 x 15 x 250[a]	11250.00
	Total no. of labors for applying insecticides 3 x 8 x 250.00[a]	6000.00
	Nokotap 6G (for 3 times) 50 x 110.00 [b]	5500.00
	Total cost	**22750.00**
Package 7	Total no. of labors for using infested cane cutting 6 x 4 x250[a]	6000.00
	Total no. of labors for de-trashing 3 x 15 x 250[a]	11250.00
	Total no. of labors for applying insecticides 3 x 8 x 250.00[a]	6000.00
	Nokotap 6G (for 3 times) 50 x 110.00 [b]	5500.00
	Total cost	**28750.00**
Package 8	No management cost at all	**00.00**
Package 9	No management cost at all	**00.00**

[a] = Labor cost 250.00 Tk/day

[b] = Nokotap 6G = 80.00 Tk.